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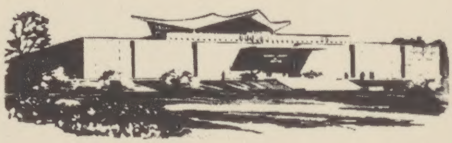

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HYGIENE

AND

PUBLIC HEALTH

BY

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SEVENTH EDITION, WITH ILLUSTRATIONS

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PREFACE TO SEVENTH EDITION

THIS edition has been thoroughly revised and enlarged, where necessary, so as to embody the advances in Public Health and Sanitary Science that have taken place since the last edition was issued.

The chapter which in the last edition was devoted to Sanitary Law and Administration has been omitted, as in the opinion of the authors this subject cannot now be treated satisfactorily in a single chapter. Public Health students are advised to consult one of the books which, being entirely devoted to this subject, can treat it with the necessary fulness. The omission of this chapter has allowed the introduction of much new matter without any increase in the size of the volume.

The authors desire to make an acknowledgment of valuable assistance from Dr. M. E. Delafield, M.C., D.P.H., and Mr. Marchant, M.R.S.I., in the preparation of this edition.

L. C. P.
H. R. K.

May, 1923.

CONTENTS

LIST OF ILLUSTRATIONS

HYGIENE AND PUBLIC HEALTH

CHAPTER I

WATER

WATER is a prime necessity of life. Without it, terrestrial animal and vegetable life must cease to exist. The earliest settlements in all countries were, therefore, made in the neighbourhood of water. Towns and villages sprang up on the banks of streams and rivers, on the shores of lakes and in the neighbourhood of springs; or water was obtained from the soil around these early settlements by shallow excavations or wells. In modern times, sites for dwellings are not necessarily limited to a small area around a natural source of water. Our engineering knowledge enables us, on the one hand, to obtain water by means of wells and borings from great depths beneath the surface of the earth, and on the other, to convey water from a distance by means of conduits to the places where it is required.

SOURCES OF WATER—COLLECTION AND STORAGE.

The natural sources of water are the rain and snow which fall on the surface of the earth. When the rain has reached the surface of the ground, it is disposed of in the following ways: a portion (*a*) is evaporated; another portion (*b*) flows off in the direction of the inclination of the surface; whilst a third portion (*c*) sinks into or percolates through the interstices of the soil.

The amount of rain that evaporates depends upon the temperature of the air. The higher the temperature, the greater the evaporation. If the inclination of the surface is *nil*, or only very slight, and the soil is of some depth and of a porous nature, the larger portion sinks into the soil or *percolates*. If, however, the inclination of the surface is great and the soil is not porous, but more or less impermeable to water, the greater

portion of the unevaporated rain flows down the incline. It is this portion which forms or helps to swell the brooks, streams, and rivers, which are the natural drainage channels of the locality. In very porous soils, such as pure sand or coarse gravel, the rain so rapidly sinks into the interstices of the soil that the evaporation, even in summer, is but slight. In nearly all other soils, however, the amount of rain evaporated greatly exceeds the percolation, even in winter.

The portion that percolates, after a certain deduction that must be made for the moisture absorbed by the roots of vegetables and grasses growing on the surface, and which is subsequently evaporated from their leaves, helps to form and renew the undergound sources of water. These are made available to man by natural outlets as springs, or by artificial tappings in their subterranean depths through wells.

In its passage through the soil, the water absorbs carbonic acid from the ground air, which is very much richer in this gas than ordinary atmospheric air. This water holding carbonic acid gas in solution is capable of dissolving some of the mineral constituents of the deposits through which it passes.

Rainfall.

The rain that falls on the roofs of houses can be collected and made available as a means of water supply. To calculate the amount of water supply per head from this source, we must know the amount of roof space per individual (the slope of the roof must not be taken into account, but merely the area of horizontal surface covered by the roof), the average amount of yearly rainfall, and the average amount of evaporation of the rainfall.

The amount of yearly rainfall varies considerably in different parts of England. In the Eastern Counties the average is less than 25 inches per annum. Throughout the remainder of England the average is from 30 to 40 inches per annum, with very much larger amounts in the mountainous and hilly districts of Devonshire, Wales, Cumberland, and Westmorland (60 to 200 inches per annum). The expression "an inch of rainfall" signifies that one cubic inch of rain-water has fallen upon each square inch of horizontal surface. (For description of rain gauge see Chapter VI.)

Rain is also sometimes collected from prepared surfaces of

ground, which, together with the storage reservoir or open tank, should always be railed off to keep live stock away. The surface of a certain area of land in an exposed situation is rendered impermeable by a covering of slates, asphalt, or cement, and sloped towards an outlet pipe or pipes leading to a tank or reservoir. In estimating the amount of water that can be obtained from such a surface calculations may be facilitated by remembering that one inch of rain delivers 4·673 gallons on every square yard, or 22,617 gallons (101 tons) on each acre.

The amount of evaporation from the surfaces of roofs may be taken as averaging throughout the year 20 per cent. of the rainfall. There is more evaporation from tiled than from slated roofs, and from roofs of low than of steep pitch. The evaporation is greatest where the rainfall is least, and vice versa. If the amount of roof space per head is 60 square feet, and the rainfall 30 inches in the year, deducting one-fifth for evaporation, 120 cubic feet or 748 gallons is the amount available for each person in a year, which is equal to about two gallons daily. This is the amount available from the rainfall—30 inches—of an average year. It has been found from a great number of records of rainfall extending over a long series of years in different places, that the rainfall in the driest year is usually one-third less than the average fall, whilst in the wettest year it is one-third greater than the average. So that in a very dry year in the example given above, the amount of water available may be only $1\frac{1}{3}$ gallons daily per head, whilst in a very wet year it may be $2\frac{2}{3}$ gallons.

Rain, as it leaves the clouds, is water pure and simple, free from all foreign ingredients. In its passage through the air to the earth it may collect various impurities, gaseous and suspended. The rain falling in towns is found to have absorbed sulphurous and sulphuric acids, the latter being always present in the air of towns from combustion of coal and coal gas, and to contain numerous sooty particles.

It also appears that the rain washes out of the air countless bacterial and fungoid organisms and their spores. The rain which first falls after a period of dry weather contains far larger numbers of bacteria than that which falls later in a storm; 200,000 germs per litre is not an unusual quantity under such circumstances. During the warm months of the year, the number of bacteria in the rain exceeds those found in the rain of winter

and early spring. The greater number of the organisms in rain are micrococci. Besides bacteria, pollen of grasses and flowers, microscopic plants, such as *Protococcus pluvialis*, and spores of fungi, are occasionally found in rain, the latter being on rare occasions in sufficient quantity to cause a localized fall of what is known as "coloured rain"; but dust, possibly of volcanic origin, or derived from vast sand deserts, is sometimes responsible for falls of coloured rain.

Rain is thus seen to be a great purifier of air, for it washes out of it gaseous and solid impurities, organic and inorganic. For this reason the rain which falls in the impure smoke and soot-laden atmosphere of large towns is unfit to drink.

When roofs are used as collecting surfaces for rain-water, they should be kept clean and free from vegetable growth. The troughs of roofs are seldom properly laid with a sufficient fall, and often sag, so as to allow soot and other dirt to accumulate in them, together with stagnant water, so that the water collected is disagreeable both in taste and appearance. It is desirable that the first portion of rain which falls and descends from the roof should be rejected, as it is liable to be much polluted with soot, vegetable matter (leaves), and animal matter (excrement of birds, etc.) washed off from the slates or tiles. After the first washing the remainder of the water may be collected and stored. Robert's Rain-water Separator, which can be fixed on the downward course of the rain-water pipe, effects this purpose by allowing the first portion of water that passes through the apparatus to run to waste. After a certain time, a part of the apparatus which is balanced on a pivot cants over, owing to its centre of gravity being altered as one of its compartments fills with water, and the water escapes into another pipe, which conducts it to a storage cistern. Rain-water should always be stored in as pure a condition as possible, otherwise the storage receptacle becomes coated with foul matters, which decompose in the water. The water should be collected in tanks of cast iron, slate, cement concrete, or brick, lined with cement. They should always be above ground, and on the north side of the house. Two at least should be provided, so that one can be cleansed without interfering with the supply. They should be deep, 5 or 6 feet in depth, so as to keep the water cool, and to allow of clarification of the water by settlement. There should be a tap connected to the bottom of the tank, by the opening of which all

the sediment can be allowed to escape when the tank is nearly empty. The supply tap should be fixed at 6 inches above the bottom, and should have a minute opening on the air side of the spigot, through which, as the water flows out, air is drawn in and thoroughly mixed with it, thus aerating it effectually and improving its flavour. An advantage of underground storage is that the water does not get frozen in the winter or unpleasantly hot in the summer. But, on the other hand, the tanks are more difficult of access. Underground tanks must be built of sound masonry or brickwork and lined with hydraulic cement. They should rest upon a bed of concrete and be covered over with arches of masonry or brickwork; and if there is a special danger of polluting material gaining access to the tank, their walls should be surrounded with at least a foot of well-puddled clay.

Rain-water is especially useful for cooking and washing on account of its *softness*—that is to say, its freedom from the salts of lime or magnesia in solution. When these salts are dissolved in a water they render it *hard*. Hardness is usually reckoned as equivalent to so many grains of chalk (or carbonate of calcium) per gallon of water. A water containing more than 10 grains of chalk or its equivalent in other salts (sulphate of lime or magnesia, carbonate of magnesia, etc.) to the gallon is said to be hard. Hardness due to the presence of carbonate of calcium, held in solution by carbonic acid, is said to be *temporary*; for when the water boils, the carbonic acid is driven off, and the chalk, no longer able to remain in solution, is precipitated.

It is this deposit of chalk which causes the fur on the bottom and sides of boilers and kettles. When meat or vegetables are cooked by boiling in hard water, a certain amount of the hard material is deposited on their surfaces, which either hinders the proper penetration of the heat into the interior, or prevents solution of the soluble materials when this is desired. The fur lining is also a non-conducting material, and impedes the passage of heat from the fire to the contents of the boiler or kettle, thus causing a waste of fuel. This fur lining is one of the causes of the boiler explosions from which loss of life not infrequently results. To reduce the possibility of such explosions the following precautions are desirable:—The boilers should be of wrought iron, properly tested; they should be periodically inspected and cleaned; pipes connected with them should not be carried up

external walls where they may be affected by frost, and the cisterns should also be in well-protected positions; the safety valve should be accessible, easily adjusted, and sensitive to variations of pressure.

Great waste of soap, too, is caused by the use of hard water in washing. When the water is hard, the lime or magnesia combines with the fatty acid of the soap, forming a curdy precipitate; and all the lime or magnesia of the water must be so combined before a lather can be formed. Consequently a certain amount of soap is wasted. One grain of chalk wastes about eight grains of soap.

The hardness of rain-water is generally less than half a degree; that is to say, it is equivalent to less than half a grain of chalk to the gallon of water; hence its value for domestic purposes. Rain-water should never be allowed to run to waste where the water derived from other sources is hard. There is one great disadvantage possessed by rain and other soft waters, namely, their liability to dissolve lead, iron, or zinc if left in contact with these metals. Consequently cisterns of lead, iron, zinc and even galvanized iron in some cases, should not be used to store soft water; and such water when collected from lead roofs should not be used for drinking.

Upland Surface Waters.

In hilly districts, the water which flows off the hills in the form of rivulets or streamlets can be collected and stored by building an earth and masonry dam or barrier across the outlet of the valley to which the streams converge. By this method of collecting in "impounding reservoirs," large artificial lakes may be formed—capable of holding a supply sufficient for several months—at suitable elevations above the towns which they supply with water. A certain amount of "compensation" water (usually estimated at one-third the amount impounded) must be allowed to pass down to any mill-owners on the streams from which the waters have been diverted.

Large storage reservoirs for such waters are made by excavating or embanking the soil, and then lining the floor and sides with concrete or well-puddled clay; common mortar must not be used, as the water takes up the lime. Their position should be such that a jet reaching 20 feet above the highest house to be supplied is assured by gravitation alone, otherwise the water

has to be pumped to a higher elevation. Means are generally taken for diverting the tributary streams from the storage reservoir when these get foul in times of flood, by means of a by-wash.

The size of a storage reservoir for a catchment area will depend upon the numbers of the community requiring the water, and upon the mean rainfall of the district. Hawksley's formula is of value in estimating the number of days' supply (x) which must be stored when a community is dependent on a rain-water supply. In this formula $x = \frac{1000}{\sqrt{y}}$; where y = the mean rainfall during the three driest consecutive years—which is usually about one-fifth less than the average. In this country from 120 to 130 days' supply has to be stored.

The average annual amount of evaporation from an exposed body of water reduces the depth by some 30 inches over the whole surface; therefore there is an advantage in diminishing the exposed area of the water by constructing deep reservoirs, rather than shallow ones.

Peaty matter is very frequently present in the upland surface waters of mountainous districts, often imparting a decidedly yellow or brownish hue to the water. It may be removed by filtering the water through beds of fine, sharp sand, as is done at Vartry (Dublin).

Under the heading of Upland Surface Waters may also be ranked the waters derived from natural lakes in mountainous districts. Upland surface and lake waters, in their comparative freedom from mineral matters, approach more nearly to the composition of rain-water than water derived from any other source. Many of the manufacturing towns in Great Britain are supplied with upland surface waters.

Occasionally the water of lakes and open reservoirs becomes contaminated by the growth and subsequent decay of algæ and other microscopic organisms. In some instances so abundant is the growth of the organism that the water becomes coloured red or green-blue, according to the nature of the organisms, and is also turbid and evil-smelling. Beyond the unpleasantness arising from the odour and turbidity of the water, and the disturbance of the sand filter-beds when the reservoir water is subjected to filtration, it does not appear that this contamination induces any injurious effect upon the health of the consumer.

Reservoirs that are covered over and protected from light are not nearly so subject to the growth of algæ.

The quantity of water that can be collected and stored in an impounding reservoir amongst hills can be calculated with some approach to accuracy if the area of the catchment basin, the average rainfall, and the average amount of percolation, evaporation, and flow of the rainfall off the surface, are known. Records of the rainfall, percolation, etc., extending over a long series of years are necessary for this purpose. The loss from evaporation in open reservoirs may reach to $\frac{1}{6}$ of an inch per day in summer, the average throughout the year varying from $\frac{1}{12}$ to $\frac{1}{16}$ of an inch daily. The area of the catchment basin or gathering ground can be ascertained from a 6-inch ordnance map. It is in many cases a district enclosed by a ridge line, which is continuous except where the water finds exit; or if the ridge line is complete and the water does not find an exit, a lake or natural reservoir is formed. The main ridge line may give off branches, and thus produce subsidiary or secondary catchment basins.

In 6-inch ordnance maps, contour lines, which are lines of equal altitude, are drawn at every 25 feet of elevation. Ridge lines, or watershed lines, indicate where the ground is higher than that immediately adjacent on each side, the land sloping from them on both sides. On the ordnance map will also be found the Bench Mark figures, which indicate in feet the height of the particular spot above ordnance datum. If the place noted by any of these figures be visited, there will be found a B. M. or broad arrow marked on some object, such as a milestone, church-wall, rock, etc.

The maps of the Ordnance Survey of the United Kingdom are published in the following scales: (1) $\frac{1}{4}$ inch to the mile, or $\frac{1}{253440}$ the actual measurements of the ground. This map shows a considerable area of country in one sheet. (2) One inch to the mile, or $\frac{1}{63360}$ the actual measurements of the ground. This is the general road map of the country. The outline edition shows contours at 100 feet intervals up to 1,000 feet, and above that height at 250 feet intervals, and numerous spot levels along the roads. (3) Six inches to the mile, or $\frac{1}{10560}$ the actual measurements of the ground. This map shows houses and fields and boundary lines. Altitudes are shown as on the 25-inch map, and contours are shown at 50 ft., 100 ft., and at 100 ft. intervals up to 1,000 ft. above sea level. (4) Twenty-five inches to the mile, or $\frac{1}{2500}$ the actual measurements of the ground. This map shows the details of buildings, and the

boundaries and areas of fields, etc. It shows levels of bench marks along the roads to one place of decimals, but does not show contours. (5) Town maps, with the exception of London, Dublin, Belfast, and some smaller towns, are on the scale of 10·56 feet to the mile, or $\frac{1}{500}$ the actual measurements of the ground, for all towns which at the time of the survey had 4,000 inhabitants and upwards. The scale is large enough to show doorsteps, the thickness of walls, and the divisions between buildings. It also shows all objects connected with water-supply, lighting, and drainage, such as hydrants, lamp-posts, sewer-manholes, and gratings. Levels are shown along many of the streets, and bench marks showing to two places of decimals the altitude above mean sea level. Areas are not shown on town plans, nor are contours. In London, Dublin, and Belfast the scale adopted is 5 feet to the mile, or $\frac{1}{1056}$ the actual measurements of the ground.

The altitudes on the maps are those above ordnance datum or mean sea level at Liverpool, which is 0·65 feet below the mean level of the sea round the coast. Trinity high-water mark at the entrance of the London Docks is 12·48 feet above ordnance datum. Surface levels are shown in feet along the roads on the 6-inch maps thus + : on 10-feet town plans one decimal is given. Altitudes are shown thus "↑ B.M. 57·4." B.M. means the Bench Mark cut on buildings, walls, etc., and at this spot the Bench Mark is 57·4 feet above ordnance datum.

Waters collected from upland surfaces are liable to pollution from shepherds' huts and farmhouses and the droppings of animals allowed to feed upon the collecting area. Such pollutions should always be reduced to the lowest possible amount.

Streams and Rivers.

Streams near their sources, and passing through uncultivated land on hills and moorlands devoid of human habitations, are good sources of water-supply; they mainly represent those upland surface waters which have already been considered.

Streams and rivers in their course through cultivated valleys, with towns and villages on their banks, furnish water which must always be regarded as undesirable, and in many cases as dangerous for drinking purposes.

The composition of river water, as regards its mineral ingredients, is most variable. Fed from a variety of sources, by springs and streams in the uplands, by surface drainage, by springs in their beds, and by other streams and rivers throughout the whole of their course, rivers are a combination of spring and surface waters, and present sometimes mainly the characteristics of the one and sometimes those of the other.

All rivers, as being the natural drainage channels of the surrounding land, must be subject to pollutions of animal origin. The surface and subsoil drainage from manured land under cultivation, the sewage effluents from isolated houses, the slop waters and the sewage of villages and sometimes even of towns, and the waste products of industries on their banks frequently flow into the river. Towns, as a rule, draw their supply of water from a river above the spot at which the sewage of the town is discharged. But the intake of the next lower town on the banks of that river must necessarily be from a stream already polluted with sewage; and the question arises, Can a river once polluted with sewage, and with all the possibilities of specific disease-contamination thereby introduced, ever be a safe source of supply below the point of pollution?

When sewage or other polluting liquids are discharged into rivers, they are more or less diluted with the river water, the amount of dilution depending on the comparative volumes of sewage and river water which are thus mixed together. If the river into which the sewage is discharged consists of clean and hitherto unpolluted water, the oxygen dissolved in it will, to a certain extent, oxidize the organic matters of the sewage, this destruction being very largely effected through the agency of aerobic or oxygen-requiring bacteria. If, too, the dilution of the sewage with clean water is considerable, plant life is not interfered with, but continues to give off oxygen, reoxygenating the water, and enabling the process of purification by oxidation to continue. No doubt, also, as the oxygen dissolved in the water is used up, fresh oxygen is absorbed from the air. Besides water plants, minute animals (infusoria, anguillulidæ or water worms, entomostraca or water fleas, etc.) aid the process of purification by feeding on the organic impurities of sewage. These organisms are found in countless numbers in the polluted reaches of rivers. Fish, too, if the pollution is not sufficiently great to cause serious diminution of dissolved oxygen in the water, feed on some of the elements of sewage, and aid in the process of purification; and when the current is sluggish, or in the deep and quiet pools of a rapid stream, the suspended matters of the sewage will be largely deposited.

Delépine has shown that this sedimentation, which occurs when the flow is sluggish, is a very important factor in promoting bacterial purification in river water.

The result of all these processes is that, under favourable conditions, when the dilution of the sewage with clean water is very considerable and the oxidation and purification exerted by aquatic animal and vegetable life can have free play, a stream or river, especially if it undergoes agitation and exposure to the air by flowing over rapids or by falling over weirs, is capable of being so far purified that, although it may never quite regain its original purity, it becomes at least very much improved.

The oxidation of the organic matters in sewage is not, however, the only process with which the self-purification of rivers is concerned. Of more importance is the destruction or elimination of the bacterial organisms introduced into the water by the polluting agents, more especially of those of "intestinal type," e.g., *Bacillus coli*, *Bacillus enteritidis sporogenes*, *Bacillus enteritidis* (Gaertner), and *streptococci*, with which are occasionally associated the *Bacillus typhosus* and other pathogenic organisms. It is probable that organisms of this type may persist in a polluted water which has freed itself from all other evidence of sewage contamination, and be present in such numbers as to indicate recent contamination with animal matter with all its attendant dangers. There is evidence, however, that organisms of the intestinal type, after obtaining admission to water, undergo after a time changes of a degenerative nature, probably accompanied by loss of virulence, so that they no longer comply with all the tests characteristic of the types they represent.

Sewage in drinking water is chiefly dangerous from the fact of its being liable to contain the specific organisms of disease. Cholera and enteric fever, diarrhœa and dysentery, we know to be sometimes spread by means of infected and polluted water.

When the river into which sewage is discharged is already much polluted, or if the dilution is not sufficiently great, oxidation and purification are brought to a standstill. The dissolved oxygen is then greatly diminished in amount; many forms of animal and vegetable aquatic life are injuriously affected or destroyed; decomposition or fermentation of organic matters is started, with the production of foul gases; the bed of the river becomes silted up with decaying matters, which, buoyed up by gases, occasionally rise to the surface and sink again, and a most serious nuisance results. The process is one eventually tending to

purification by resolution of complex organic bodies into their simpler elements, but in the meantime the effects of the process are most offensive.

A considerable rise of temperature will produce a like result on rivers which are having their purifying powers tested to the height of their capacity. Purification goes on so long as the weather is cool, but with a rise in temperature, certain forms of bacterial growth are stimulated and decomposition sets in, replacing the oxidizing processes.

The process of sedimentation which occurs in the deep and sluggish reaches of a river tends to the elimination of bacteria, the suspended matters in their subsidence entangling them and carrying them down. The effect of aeration and of flow is less apparent *qua* bacterial destruction; whilst as regards the undoubted powerful germicidal action of bright sunlight, in the case of a river like the Thames, with an average depth of over six feet, it is doubtful what effect the water has in cutting off the actinic rays, and, therefore, what is the precise germicidal action of sunlight or daylight at different depths from the surface, and under different conditions of clearness or turbidity of the water.

Dr. Houston has shown that if sufficient storage capacity is provided in the reservoirs for the crude river (Thames) water from the intakes, it is possible to eliminate from the water all but a very small percentage of disease-producing organisms. In eighteen experiments with unfiltered water, infected with enormous numbers of the bacilli of enteric fever, it was found that over 99 per cent. of these organisms died as the result of simple storage of the water for four weeks. The final and complete disappearance of typhoid bacilli from an artificially infected raw river water may not take place until nine weeks after inoculation.

Houston has shown that in fresh, healthy human fæces 85 per cent. of the organisms known as *Bacilli coli communis* are typical *B. coli*, answering to all the known tests for this organism, the remaining 15 per cent. being atypical, in the sense that they do not respond to all the tests. In sewage and sewage effluents the percentage of typical *B. coli* is slightly reduced, and in sewage-polluted waters there is a further reduction. In filtered waters derived from polluted sources, such as the water of the Thames at Hampton, the percentage of typical

bacilli is reduced as low as 38 after storage and sand filtration, such as is practised by the Metropolitan Water Board, in addition to the 98 per cent. reduction in total number of organisms as compared with the unfiltered crude river water. Dr. Houston is of opinion that the smaller proportion of typical *B. coli* in the stored and filtered water is evidence of elimination from the water of bacilli which are specially characteristic of fæcal matter; and therefore of purification by change of type of bacilli, apart from reduction in numbers. The elimination of the typical bacilli is relative and not absolute, as 30 per cent. of the samples of filtered water examined contained typical *B. coli* either in 100 c.c. (15 per cent.), 10 c.c. (11 per cent.), or 1 c.c. (4 per cent.) of the water. In the latter case only, however (*B. coli* present in 1 c.c.), would the water be considered decidedly unsatisfactory.

Thus it appears that even river water which has received some sewage contamination may be made reasonably safe for drinking purposes by storage followed by sand filtration; but every care must be exercised to insure the continuous working efficiency of each filter in use, and to guard against subsequent contamination of the water.

Sand acts almost entirely as a mechanical filter, but a small amount of purification by oxidation takes place. This purification results mainly from the condensation of oxygen, which takes place upon the upper surface of the sand. Dr. Percy Frankland has shown that the micro-organisms (harmless) present in unfiltered Thames water at Hampton are reduced in number on the average 97·7 per cent. by the sedimentation and filtration which the water undergoes at the hands of the Water Board, and that this reduction is largest in the case of those installations which have the largest storage capacity for unfiltered water and the slowest rate of filtration, these being factors of much influence on the chemical, as well as on the biological, characteristics of the water.

All the witnesses before the Royal Commission on the Metropolitan Water Supply (1893) were agreed that the efficiency of the sand filter-beds in intercepting bacteria is due to the formation of a superficial gelatinous deposit on the top of the sand. Green and blue algæ interweave their filaments into one felted sheet; diatoms, with their siliceous frustules and gelatinous envelopes, fill up the meshes; zooglea adhere to every particle;

and innumerable bacteria dot the whole mass (Thresh). The bacteria become attached to and entangled in the colloidal mass, and are consequently prevented from passing down into the deeper beds of sand and gravel. This filtration has been likened to the dialysis through a fine jelly, which is capable of intercepting the very smallest bacteria, if there is no rupture or loss of continuity in the material. This gelatinous film which forms on the top layer of sand consists therefore very largely of intercepted organic matter and bacteria. It appears to be sufficiently well formed to be effective in intercepting bacteria within two or three days after the filter-bed has been in use, subsequent to renewal of the top layer of sand. It follows, therefore, that the filter-bed does not attain its normal efficiency in the interception of bacteria until it has been in use at least two days after the periodical renewal. On the other hand, there is no evidence of the efficiency of the sand filter-beds, *qua* bacterial interception, being reduced by prolonged use, even for so extended a period as sixty-eight days. It would seem that the organisms tend to grow down deeper and deeper into the beds, and might possibly in time grow quite through the interstices of the filter, and so reappear in the filtered water. But owing to the thickness of sand this process must occupy a very long time. The reason why the top layers of sand should be removed and renewed periodically is to prevent other filter-beds being overtaxed, because the filtration becomes slow in old beds, owing to the thickness of the gelatinous coating, and consequent clogging of the top layers. If certain filter-beds are working too slowly, others have to be pressed, possibly resulting in inefficient filtration, in order to make up the volume of filtered water necessary for the daily supply.

The results of the Massachusetts experiments on the purification of water by filtration may be briefly summarized as follows:—

(*a*) By reducing the rapidity of filtration, and employing the finer sands, increased efficiency is obtained.

(*b*) With moderate rapidity of filtration (2,000,000 gallons per acre per diem) 1 foot of sand appears to be as effective as 5.

(*c*) The scraping off of the upper layer of clogged sand enables more organisms to pass through the filter; and it is not, as a rule, until three days after scraping that the filters regain their highest efficiency.

(*d*) Fifty-five per cent. of the organisms removed were found in the upper ¼ inch of sand, and 80 per cent. in the upper inch.

(*e*) Much less water at 32° F. passes through a filter than when the water is at 70° F., owing to the increased viscosity of the colder water.

(*f*) Shallow filters require more frequent scraping than the deeper ones, due to the greater head available in the deeper filters.

(*g*) Filters used continuously require less frequent scraping than when used intermittently.

The majority of the bacteria in adequately filtered water are attributable to post-filtration sources, the filter-beds below the slime layer, the channels, collecting drains, culverts, and wells being, of course, not sterile. The slightest disturbance, however, in the process of filtration, as, for instance, the quickening of the pace of filtration to over 100 mm. per hour, or the disturbance of the slimy covering, as in periods of frost or immediately after a filter is cleaned, tends to create an immediate increase of germs in the filtered water.

The mechanical filtration of water under pressure provides a rapid and more economical means of filtering large volumes of water. These are gravity filters, in which the rate of filtration is governed by the height of the water, or pressure filters actuated by either a head of water or by pumps. In the pressure filter the water is forced under pressure through several feet of fine sand or quartz, the cleaning of the filters (varying from every six to twenty-four hours, according to the cleanness of the water, and only every few days if the water is very clear) being effected by means of a reversed current of water. Other materials are sometimes used, such as a black, porous, magnetic oxide of iron, called Polarite. These filters can be used with or without coagulant, but in the latter case a satisfactory bacterial standard of purity cannot be obtained. The coagulant most commonly used is the sulphate of alumina, from 1 to 2 grains per gallon; and the object of its employment is to form a gelatinous cover on the surface of the mechanical filter which will take the place of the bacterial scum which forms on ordinary sand filters. It is possible to remove about 95 per cent. of the organisms originally present in the water. These filters, employed in conjunction with a coagulant, are very serviceable when dealing

with raw river waters, and also in the removal of peaty colour and iron.

The yield of a small stream, or water-course, may be approximately ascertained by taking the average width and depth of the stream over a portion of the channel where it is fairly uniform. The yield is found by multiplying the area thus obtained by four-fifths of the surface velocity in this portion of the channel. Current meters may also be employed.

Sometimes river water is obtained from deep trenches dug in the proximity of a river, and it is assumed that the water undergoes purification in its passage through the soil. Although more or less ground water is generally collected in these trenches, water of considerable purity has often thereby been obtained.

Springs.

The advantages of underground water supplies over surface-collected supplies are that large reservoirs are not required, less land is wanted, filtration is unnecessary, and there is less liability to pollution. In some springs, derived from underground waters at great depths below the surface of the earth, the mineral constituents of the water are so excessive in amount as to render it quite unfit for drinking, but valuable for medicinal purposes. There can be little doubt that the water forming these springs is, in some cases, forced out of the earth by the pressure of confined gases; but the origin of most of the springs which afford a pure and wholesome water for ordinary use is explained in a different manner.

The rain which percolates the porous strata (sand, gravel, fissured chalk, sandstone, etc.), at the surface of the earth, sinks through these strata by the force of gravity until it reaches—as it usually does at a greater or less depth—an impermeable stratum. This underground water does not always stand at the same level. It is constantly rising and sinking, and in most years these variations of level are fairly regular, both as to amount and as to the season of the year at which they occur. The highest level is usually reached in this country in February or March, whilst the lowest occurs in October or November. The cause of these variations must be looked for in the circumstances attending the rainfall.

In districts having an average rainfall (25 to 30 inches per annum), the amounts of rain that fall in summer and in winter

are very nearly equal. But in the summer months (April to September) the amount of rain that percolates is generally very small; it is only one-seventh of the summer rainfall on chalky soil. Nearly all the rain that falls in an average summer is evaporated from the surface of the soil or from the leaves of plants. The consequence is that the underground water is not replenished from the surface, and its level sinks. In the winter months (October to March) considerably more than half the rainfall percolates in most chalky soils, the remainder being lost by evaporation. The underground water begins to rise usually in November, if percolation has commenced in October, and continues to rise until it attains its maximum in March.

Occasionally it happens, as in 1879 and in 1903, when the summers were very wet, that the underground water rises during the summer months. But such years are exceptional.

The underground water is not only constantly changing its level, but it is also always moving slowly towards its natural outlet. The water tends to find its own level according to the laws of gravitation; not rapidly, but slowly, owing to the friction and capillarity which obstruct its passage through the interstices of the rocks or soil. The outlet may be into the sea or into a river, or by springs.

It has been found by observation on shallow wells that the underground water has a curved surface from its highest level to its outlet. The curve rises steeply from the outlet, but gradually becomes more nearly horizontal as the distance from the outlet increases (fig. 1). The variations in level between high and low underground water are small near the outlet, whilst they gradually increase as the distance from the outlet increases. When the level of the underground water is highest, the fall to the outlet is greatest, and, consequently, the volume of water discharged at the outlet is at its maximum.

Springs are usually divided into "main or deep" and "land" springs. Land springs are formed by the "cropping out" on the surface of the earth of the impermeable stratum which holds the underground water up, i.e. prevents it from sinking farther into the earth.

Such springs are the outlets of limited collections of underground water, formed in superficial beds of sand or gravel overlying an impermeable stratum. They are often intermittent, ceasing altogether to flow during the summer, when the under-

ground water is exhausted, and beginning again in the autumn, very soon after percolation commences. Intermittent springs are also formed where a valley cuts across the highest levels of a large volume of underground water, so that the spring flows only for a short period of every year—usually in February or March—when the highest water line of the underground water is tapped by the depression of the valley (fig. 1).

Main springs are the deep-seated springs issuing through a fault or fissure from regular geological formations, such as chalk, oolite, sandstone. They are usually perennial, flowing all the year round, but often exhibit well-marked seasonal variations, their volume increasing in winter, when the underground water level stands highest (*see* fig. 1).

Springs afford good sources of water supply for small communities, such as villages. Main springs are better than land springs, both because, as before stated, they yield water throughout the entire year, and because they are less liable to accidental

FIG. 1.—UNDERGROUND WATER CURVES.
A, high level; *B*, low level; *C*, intermittent land spring; *D*, constant land spring at sea level.

pollutions, the great thickness of strata through which the water percolates from the surface effectually dealing with any organic impurities it may contain. Such spring water is usually clear and sparkling, well aerated, and of nearly constant temperature throughout the year. It generally contains more or less of the salts producing hardness, and is, therefore, though palatable and wholesome for drinking, less well suited for washing, cooking, and manufacturing purposes than the softer waters.

To guard against pollution, the surface of the soil around the point of delivery of the spring should be walled in, and the water conducted to the surface by a short pipe. In some cases it may be necessary to collect the water issuing from a spring, and to store it in a reservoir before distribution to the houses of the consumers.

The yield of a spring may be estimated by observing how long it takes to fill a vessel of known capacity. It is well to know the average flow throughout the year.

In chalk and sandstone districts springs generally occur at points much below the level of the surrounding country, as these permeable rocks themselves form vast reservoirs. In the oolite, owing to the frequent alternation of porous and retentive strata, springs are common. In limestone regions main springs are often fed by subterranean reservoirs caused by the solution of the limestone by water charged with CO_2. The most constant and abundant springs in this country are generally in the chalk, oolite, new red sandstone, the millstone grits, and mountain limestones; and the most invariably good water is obtained from the lower chalk immediately above the greensand.

Springs may be made to supply water to houses situated above the level of their delivery if the flow is sufficient to work a ram, turbine, or other similar form of pumping engine, so that the water can be pumped up to the cistern or reservoir. Sometimes the spring water issuing from a great depth is warm or even hot. This is due to the fact that, below the level at which variations due to atmospheric alternations of temperature cease to be recognizable, the temperature of the earth increases with its depth, and the water temperature rises about 1° F. for every 50 or 60 feet of depth, on an average.

Wells.

It is usually said that there are three kinds of wells, *shallow*, *deep*, and *artesian* ; but the last is merely a variety of a deep well.

Shallow wells are those which are sunk into superficial porous beds (sand, gravel, etc.) overlying an impermeable stratum of clay or other dense rock. They tap the underground water held up by an impermeable stratum, and yield a water identical in composition with that flowing from the land springs in the neighbourhood. The depth of the well must, of course, vary with the vertical distance of the impermeable stratum from the surface of the earth; as a rule, this distance is not great, and, in fact, it is often said that shallow wells are those which are less than 50 feet deep; but it is better to keep to the definition here given.

The rural population of this country derives its water almost exclusively from shallow wells. Formerly shallow wells were also the usual sources of supply in towns; but these, in nearly all instances, have now been abolished in favour of a public supply from better sources. The Rivers Pollution Commissioners

(Sixth Report) stated that in their experience shallow wells were almost always horribly polluted by sewage and by animal matters of the most disgusting origin.

Where the level of the underground water is but a few feet from the surface, it is obvious that the surface water, which may contain impurities, has but little chance of being purified in its passage through the soil to the well. But the grosser pollutions that shallow well waters suffer from, come, not from the surface, but from leaking drains and cesspools in the vicinity, which may lead to a general contamination of the ground water of the district.

Cesspools are but rarely kept watertight, as they would then require to be frequently emptied. When sunk in a porous soil and merely lined with bricks without mortar or cement, the contents soak away, and the cesspool can be closed over and need not be opened for many years. The liquid sewage percolates through the soil and joins the underground water below. As the underground water is—as before explained—slowly but steadily moving along in the direction of its natural outlet, the position of the well in regard to the cesspool is all-important. Should the well be above the cesspool, the underground water flowing *from* the well to the cesspool, the risk of pollution is greatly diminished, so long as but little water is drawn from the well. If the well is below the cesspool, and in the line of flow of the underground water, it must infallibly be polluted with the cesspool soakage. The direction of flow of the underground water can usually be determined from the contour of the surrounding country; and this evidence can be confirmed by observations on the height of the underground water at different places, as determined by the height of the water above ordnance datum in different wells or trial holes; for the level of the underground water falls as it approaches its outlet in springs, lakes, streams, or rivers, giving rise to a curve which has been already considered (*see* p. 17).

When, however, the amount of water abstracted is sufficiently great to cause a considerable depression of the water in the well, the well then drains an area all round it in the form of a circle; and in such a case it would not matter what position the well had to the cesspool if the cesspool was included within the area drained by the well, for pollution must inevitably occur. The distance within which a well draws water to itself, when

its own water-level has been depressed by pumping, depends on the amount of the depression and on the nature of the soil.

The surface of the underground water in the area of the circle drained by a well depressed by pumping has the form of a curvilinear cone, with steep gradient near the well, but becoming more nearly horizontal as the distance from the well increases.

We have thus seen that the conditions which favour the contamination of a shallow well from cesspools or other forms of pollution are: (1) Its position as to cesspools or other sources of pollution, with regard to the flow of underground water; (2) the amount of depression of water-level in the well which may be produced at any time by pumping; (3) the nature of the soil in which the well is sunk, as regards porosity and the easy passage of water. It is quite possible, if these conditions

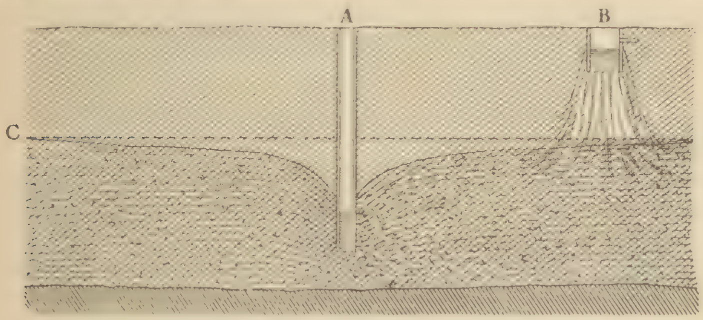

FIG. 2.—DEPRESSION OF WATER IN SHALLOW WELL BY PUMPING. A, well; B, cesspool; C, underground water curve. (After Field and Peggs.)

are attended to, to sink a well that shall be uncontaminable in or near a village, in which the shallow wells are generally polluted with cesspool soakage.

The well must be sunk in such a position as regards possible sources of pollution that the underground water flows from the well to the sources of pollution. The distance of the well from such possible polluting sources should be from 100 to 160 times the depression of the water in the well that is ever likely to be produced by pumping, this distance varying with the nature of the soil. It is very desirable to establish a "protected area" around a shallow well. The mouth of the well should be closed over, and the water raised by an iron pump; draw wells, where the water is raised by a windlass, chain, and bucket through an open mouth, are liable to accidental contamination from

refuse being thrown in, or animals falling in. To prevent contamination from impure surface washings, the mouth of the well should be protected by a coping carried up to about a foot above the surface of the ground, and the drainage water from the pump should be conducted away to a safe distance.

It is very desirable to make the walls of a shallow well impervious. When the porous stratum in which the well is sunk is of considerable depth, the sides of the well for about 20 feet should be imperviously steined with brickwork set in and lined with hydraulic cement; or cast or wrought iron cylinders may be employed for lining the upper portion. If this is done, water percolating from the surface must pass through about 20 feet of soil before entering the well, and, in its passage through the soil, the organic impurities in the water will be, to a certain extent, removed. There should, of course, be no opportunity for surface waters to pass into the well outside of the impervious wall provided. The less the fluctuation in level of the subsoil water, the more likely is the supply to be permanent, and the less the liability to contamination.

It is a noteworthy circumstance in regard to the grossly polluted waters of many shallow wells, that they are, as a rule, clear, sparkling, and very palatable. The organic filth from cesspools and drains, in its passage through even a few feet of porous soil, is filtered and deprived of suspended matters, but does not lose its dangerous properties. The shallow well into which the filth percolates is found to furnish a water loaded with ammonia and chlorides—evidences of sewage (urine) contamination—with organic matter in solution, and with nitrates and nitrites, the oxidized residues of organic matters; but yet, from its containing abundance of carbonic acid gas, the water is sparkling and palatable. Such wells, however, after a heavy rainfall, are sometimes liable to furnish a turbid and foul-smelling water which nobody would think of drinking. The heavy rain washes foul substances in the soil, derived by soakage from manure-heaps, middens, privies, leaky drains, or cesspools, direct into the well, no time being allowed for that filtering and partial purification which does so much to give the well water at ordinary times its pure and deceptive appearance.

Where suspicion is entertained that a well water is polluted, the method by which the polluting material reaches the well may sometimes be ascertained by the use of solutions, which

either by reason of their colour, taste, or chemical properties, can be easily identified, even when largely diluted. For this purpose strong solutions of common salt, lithia salts, an alkaline solution of fluorescein, paraffin oil, or an emulsion of *Bacillus prodigiosus* have been employed. When introduced into the drain, cesspool, or other supposed source of the mischief, such solutions will within a few days, if the supposition is correct, be found in the well water. For most purposes fluorescin, along with a similar quantity of sodic hydrate, is preferable to the other substances, as it is very soluble, has great colorific power, is easily identified, and is harmless in small traces. One grain imparts a visible green fluorescence to over 500 gallons of water. Emulsions of *Bacillus prodigiosus* are of use where leakage into a well from the surrounding soil is suspected, and it is desired to ascertain if the filtering power of the soil is sufficient to arrest the passage of bacterial organisms contained in sewage or other polluting liquids.

In making an examination of a well, the cover should be taken off, and the sides of the well should be carefully examined for evidence of liquids finding their way through the brickwork, or for the discoloration of the sides due to past leakages. The position of the pump and the rising main should be noted, and the point at which the latter leaves the well should be examined. The depth of the water in the well, the distance of the water-level from the ground surface, and the depression of water-level caused by pumping should be ascertained, also the time that elapses before the original water-level is restored after pumping ceases. The surroundings of the well should be noted, the distances from possible sources of pollution, and the porous or impervious nature of the soil and subsoil. The condition of the ground around the well, and the method of disposal of the waste water from the pump, should also receive attention. If samples of the water are taken, it is often desirable that a sample should be taken from near the surface of the water, as well as from near the bottom, as polluting materials may be very unequally distributed in stagnant water, undisturbed by any currents.

Polluted shallow well waters are usually hard, and therefore unsuited for domestic purposes. The hardness is sometimes due to the polluting liquids which find their way into the well, but little being caused by the mineral salts present in the strata

through which the well is sunk. Another source of pollution of shallow wells is the vicinity of graveyards, especially when the subsoil water is liable to rise up to the level of the coffins.

Tube wells are contrivances for obtaining water from superficial porous strata by means of borings. They were largely used during the Abyssinian campaign, where the occupation of any piece of ground was necessarily temporary, the tube being quickly sunk and as quickly withdrawn. An iron tube with a steel nozzle and perforations at its lower end for the passage of water is driven into the ground by a driving weight or "monkey"; before it has altogether disappeared into the ground another length of tube is screwed on, and this is then driven in. Successive lengths of tube are attached until a depth of 20 to 28 feet is reached, when a hand-pump is screwed on the top and the water is pumped out. Difficulty is often experienced from sand blocking the lower part of the tube and the perforations. The sand must be dislodged by a clearing tool, or pumped out until a space free from sand is formed around the nozzle, and the water issues clear and bright. These tube wells are most suitable where the distance of the water from the surface of the ground is not more than a few feet, and it is sometimes advantageous to drive one from the bottom of an ordinary well to increase its yield. They can be used in gravel, coarse sand, or chalk, but their use in clay soils, marls, or fine sand is not satisfactory.

Deep wells are those which are sunk to considerable depths in search of water through regular geological strata such as chalk, oolite, and sandstone. Those also are known as deep wells which pass through a superficial porous bed and an underlying impermeable stratum to reach water-bearing strata below, though often at no great distance from the surface. In sinking a deep well, as soon as the water-bearing strata are reached the water often rises rapidly, and may even overflow at the surface.

If the sides of a deep well of this nature are properly steined with brickwork set in cement as far down as the impermeable stratum, surface waters and underground water resting on this stratum are entirely excluded, and the well is freed from those sources of pollution which so often contaminate shallow well waters. In hard chalk, new red sandstone, oolite, and limestone, the wells require no lining, but in clays, marls, and in all free and broken strata they should be steined.

The water collected from deep wells has usually travelled a long distance since it fell as rain on the surface of the earth; for the outcrops of the water-bearing strata on the surface, which are the catchment areas for the rain, may be many miles from the spot at which the well is sunk, as is the case with the deep wells in the chalk sunk into the London basin.

Owing to the joints and fissures in the chalk allowing a free passage for water, the distance which a well or boring drains, when its water-level is depressed by pumping, is very great; and thus borings at considerable distances from one another are mutually affected by continued pumping in any one of them. If a boring in the chalk should not happen to open up any fissures or cracks, it may supply but a limited quantity of water, or none at all.

In making these borings it is usual to excavate a wide well-hole for some depth, from the bottom of which a bore tube of small diameter (6 to 15 inches) is sunk. The water should rise through the bore tube in sufficient volume to form a reservoir in the lower part of the well-hole, from which it can be pumped to the surface from considerable depths. Boring tools of large diameter have been recently introduced, and these are found less costly, whilst the borings are more easily made. At some new works in the chalk at Southampton, the bore tubes are 6 feet in diameter. It has been in many cases found that the driving of headings ("galleries") and adits horizontally below the water-level is more effective in increasing the yield of wells than deepening them, as the area of collection of water is thereby increased, and there is a greater likelihood of striking the fissures through which the largest volumes of water are moving.

Artesian wells, so called from the province of Artois in France, where they have long been in use, are formed when a boring taps a subterranean reservoir confined in a permeable stratum by impermeable strata above and below, the permeable stratum having its outcrops on the surface at considerably higher levels than the surface of the ground where the boring is sunk. The subterranean reservoir is consequently basin-shaped; and the water, when tapped at the lower part of the basin, strives to regain its level by flowing up the boring and spouting out at its mouth. The waters which feed these wells often come from a great distance, the outcrops of the permeable strata on each side of the basin being sometimes 60 or 70 miles from the well in

a straight line. The best artesian wells are found in the chalk.

The water supplied by deep wells is generally remarkably free from organic impurities, even when sunk in the midst of large cities. Nitrogen, as nitrates and nitrites, is usually present in deep well waters; the other mineral constituents of the well water depend chiefly on the strata through which the water has percolated, and on the solubility of the component elements of these strata by water charged with carbonic acid.

In the near neighbourhood of the sea there is a danger of the infiltration of sea water into deep wells, especially when sunk in chalk formations. Such infiltration is recognized by an increase in the amount of chlorine in the well water, and is probably due in some cases to excessive pumping causing considerable depression in the water-level of the well. It has happened that the brackishness so caused has rendered a town water supply quite unusable for domestic purposes, and has given rise to diarrhœa and other evidence of gastro-intestinal disturbance among some of those drinking it.

The yield of water from a well can only be ascertained by pumping down to a certain level, and observing the length of time required for the water to regain its original level. In this country the largest supplies of deep well water are obtained from the chalk, the oolite, and the new red sandstone.

Although deep wells, when protected from surface drainage in their upper parts, are but rarely polluted, even when situated in the centre of towns, it does occasionally happen that liquid soakage from sewers or cesspools finds its way into fissures[1] in chalk or sandstone, which conduct it to the water of the well, unfiltered and therefore unpurified, and pregnant with danger to the consumers. Deep wells in Liverpool and other places have been closed for this reason.

Systematic investigations in order to gauge the extent of the pollution of village water supplies are desirable; indeed, they are demanded under the provisions of the Public Health (Water) Act, 1878. In some cases, where these have been made, practically every well water in a village has been shown to be dangerously contaminated.

[1] Faults, fissures, joints, or dislocations are defects which are due to the excessive strain of contraction when drying or to movements of the earth's crust.

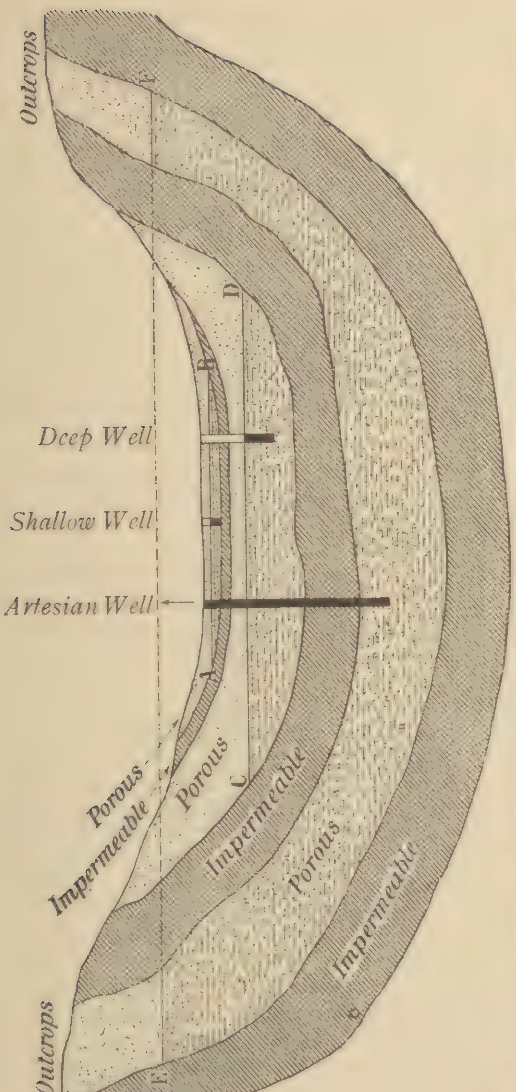

FIG. 3.—DIAGRAMMATIC REPRESENTATION OF STRATA; SHOWING SHALLOW, DEEP, AND ARTESIAN WELLS.
A, B, subterranean water level in surface strata; C, D, subterranean water level in deep strata; E, F, subterranean water level in water-bearing strata supplying artesian well.

When it happens that villages are sufficiently convenient to an existing water main which is taking water to some larger community, a public supply may sometimes be obtained from that source at a reasonable cost. Then, again, where larger

villages cluster conveniently, a combined water supply may be provided at a less cost than a separate supply to each village would incur.

The provision of a public village supply may be made as cheap as possible by simply carrying a main from the storage reservoirs through the village, and providing a few pillar taps in selected positions. To meet the special circumstances of the smaller villages scattered at considerable distances from each other, the existing polluted wells or springs should be closed, and, where practicable, one or more deep wells, or even one or more new shallow wells (where the yield is satisfactory) specially constructed (concrete tubes are cheap and satisfactory), and placed in selected positions, should be provided for the use of the villagers.

The following facts will be found of value in seeking for water. In comparatively flat districts, trials should be made by Norton's tube wells at the lowest sites on the survey. The part most covered by herbage is probably the site where the water reaches nearest to the surface. The same fact is sometimes denoted by localized early morning mists or swarms of insects. The nearer the sea, the more likely is water to be found, but if too near the sea the water may be brackish.

In hilly country a search should be made in the deepest valleys, especially the side of the valley towards the highest hill, and at the junction of two long valleys. If there is any evidence of an original watercourse at this point, water is often found at no great depth. A knowledge of the dip[1] of the strata in the district, and the situation and area of their outcrop, is of the greatest value in such an investigation.

Pumps.

Suction Pump.—Fig. 4 shows a section of a common suction pump, which works by the exhaustion of air inside a cylinder, by means of the upward stroke of a piston, the atmospheric pressure on the surface of the water forcing the water up through the suction pipe into the cylinder. The downward stroke of the piston forces the water through the piston valve, and the next upward stroke delivers it through the spout of the pump. Where water has to be delivered at a height above the pump, the spout is replaced by a pipe (the

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[1] The term "dip" refers to the inclination of the strata to the horizon: an originally horizontal deposit dips from movements of the earth's crust. A "strike" is a line drawn at right angles to the direction of the dip.

rising main) with a valve at the point of attachment to the cylinder, which permits water to enter the rising main, but prevents its reflux into the cylinder. In this class of pump the lift of water is effected by the upward stroke of the piston, and the delivery is in consequence intermittent. At each up-stroke of the piston the suction or clack valve C is opened and the piston valve B is closed; at each down-stroke the action of the valves is reversed. The height of the clack valve C above the lowest level of the water to be raised must not be more than 25 feet. Although theoretically atmospheric pressure is capable of supporting a column of water 33·9 feet in height, practically the most perfect vacuum obtainable in a suction pump is only equivalent to 25 feet of head, and these pumps work best with heights of less than 15 feet.

Force Pumps.—Sections of force pumps are shown in figs. 5-6. These pumps are used where water has to be raised to a height exceeding 25 feet, as from deep wells. In each case the water is raised by suction into the pump, but whilst in the single-acting pump (fig. 5) the delivery is intermittent, in the double-acting pump (fig. 6) the flow of water is continuous.

Semi-rotary Pumps.—These are suction and lift pumps, in which the water is raised by the suction induced in a small disc-shaped cylinder by means of metal valves rotating in a half-circle at a considerable speed. These pumps are small, occupy little space, and are easily worked by a lever with vertical action.

Centrifugal Pumps.—These are used (*see* fig. 7) where large quantities of water or sewage have to be raised through a moderate lift, not exceeding 25 feet. The apparatus is simple and compact, consisting of revolving fans, which by their rapid revolution cause a vacuum, and draw water through a suction pipe into the centre of the rotary wheel. The centrifugal action set up by the fans causes the water to be ejected through the delivery pipe. The wheel is made to revolve by belting passing round the fly-wheel of a steam, gas, or oil engine.

Chain Pumps.—In this pump, water is raised by means of a series of small buckets attached at equal distances to an endless chain, which passes round a vertical wheel above and dips into the water below. Instead of the buckets, the endless chain may be enclosed in a tube, and carry a number of equidistant diaphragms provided with leather washers just large enough to work up and down inside the tube. The vertical wheel is made to revolve, and the little buckets, or the diaphragms, in their ascent lift the water, and discharge it into a spout at the top of the apparatus. These pumps are especially suitable for raising sewage or other water containing suspended matter, which is apt to clog and derange the action of ordinary pump valves.

Pulsometers.—These are mostly used for temporary pumping purposes. The pump consists of two vessels with a ball valve at the top, steam from a boiler being admitted alternately into each vessel. The steam forces the water out of the vessel into the rising main or delivery pipe; and the condensation of the steam, by contact with the cold sides of the vessel, causes a vacuum, the pump thus having a suction effect on the water over which it is suspended, which

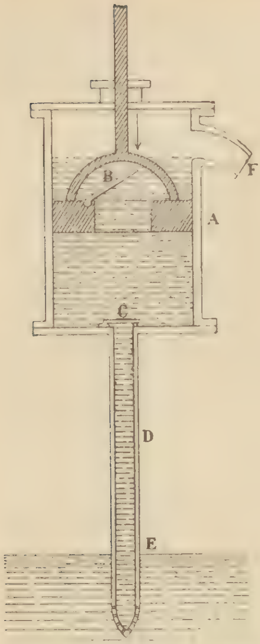

FIG. 4.—SUCTION PUMP.

A, piston; B, piston valve; C, suction or clack valve; D, suction pipe; E, water; F, spout.

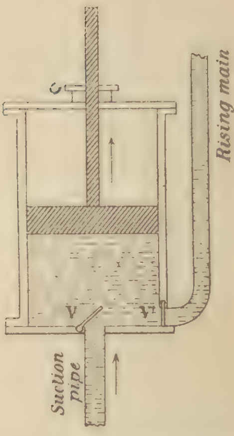

FIG. 5.—SINGLE-ACTING SUCTION AND FORCE PUMP.

V, V^1, valves.

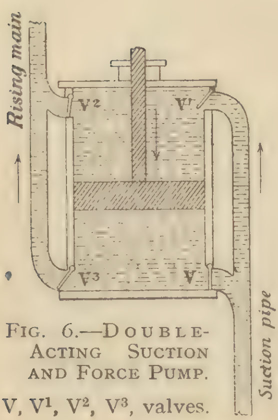

FIG. 6.—DOUBLE-ACTING SUCTION AND FORCE PUMP.

V, V^1, V^2, V^3, valves.

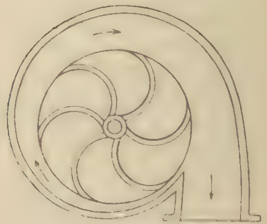

FIG. 7.—CENTRIFUGAL PUMP.

rises through a suction tube and suction valve into the pulsometer. Thus alternate condensation and discharge takes place in each of the two vessels composing the pulsometer, and there is a continuous discharge of water so long as steam is supplied.

Water-wheels.—By the use of water-wheels the motive power of a running stream can be utilized in raising water to a height. Vertical water-wheels are of three kinds: (1) *Overshot*, when the water is delivered on the top of the wheel; (2) *Breast*, when the water is delivered near the centre of the wheel; and (3) *Undershot*, when the wheel is driven from the bottom by the impact of a strong current. For overshot and breast wheels the stream must be dammed, as seen in the common mill dam and wheel. By suitable gearing the circular motion of the wheel is transformed into the reciprocating motion of the piston rod of the pump used to lift the water of the well or reservoir.

Hydraulic Ram.—When water flowing rapidly in a pipe is suddenly checked, there is an increase of pressure on the interior of the pipe.

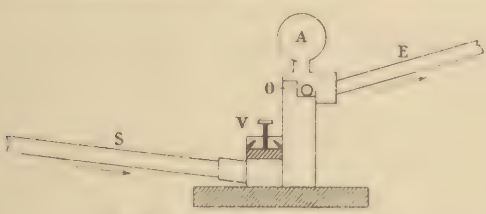

FIG. 8.—HYDRAULIC RAM.

V, self-acting pulsating discharge valve; A, air vessel; O, ball valve; S, supply pipe; E, delivery pipe.

This increase of pressure is known as ramming, and is used to force a certain proportion of the water flowing down the pipe to a height above the point at which ramming takes place. The apparatus is shown diagrammatically in fig. 8. Water descends with considerable velocity down the supply pipe S from a stream or reservoir, and runs to waste through an opening at V, which is guarded by a valve. But the momentum of the water in its flow is sufficient to overcome the weight of the valve, which is raised and closes the orifice. The flow of water thus momentarily checked causes an increase of internal pressure in the apparatus, and the ball valve O is opened, allowing water to pass into the air-chamber A, where the cushion of compressed air drives the water steadily up the pipe E to the storage tank. As soon as the pressure is reduced by the opening of the ball valve O the discharge valve falls, and water again escapes at V, until the velocity of flow reaches the point at which the discharge valve is again raised, and the cycle of events is reproduced. A fall of 10 feet from a stream or reservoir to the ram is sufficient to raise water to a height 150 feet above the ram.

Composition of Water from Various Sources.

The nature and amount of the organic pollution to which water from various sources is liable is such a variable quantity that it is useless and misleading to attempt any classification under this head; for it is local circumstances that will determine whether a shallow well water is polluted or a deep well water is pure. Generally speaking, however, the purest waters are derived from deep springs and wells and upland surfaces, while the waters from the subsoil, from cultivated surfaces, and from rivers are especially liable to be organically polluted. But the character of the soil and subsoil from which the water is collected influences its composition to an extent which, though variable, may be approximately defined by chemical analysis.

1. *Surface Waters.*—Those waters collected from the hard surfaces of the practically impervious rocks which support little animal or vegetable life are soft and pure. They commonly contain less than 10 parts of total solids, 5 of total hardness, 1 of chlorine, and 0·1 of nitrogen as nitrates, in 100,000 parts of water. The mineral solids consist mainly of sodium carbonate and chloride, and a trace of lime or magnesia. The variable amount of organic matter, which is often exclusively of vegetable origin (peat), yields practically no free ammonia; but the organic ammonia figure and that of oxygen absorbed by organic matter may be high, in which case the water is often highly coloured and acid in reaction. Such characters are presented by the waters collected from the surfaces of the igneous metamorphic (quartz, mica, granite, etc.), Cambrian, Silurian, and Devonian rocks.

The waters from the surface of the non-calcareous carboniferous rocks (Yoredale rocks, millstone grits, and coal measures) are very similar; but those which have flowed over the surface of the calcareous carboniferous rocks—the mountain limestone and limestone shales—differ from the former in possessing a moderate degree of hardness, higher total solids, and a neutral or faintly alkaline reaction. The mineral solids consist chiefly of sulphate and carbonate of calcium and magnesium.

Surface waters from the lias, new red sandstone, magnesian limestone, and oolite may vary considerably in their composition. The total solids are generally between 10 and 20 parts per 100,000, the total hardness between 10 and 15 parts, the chlorine is below

2 parts per 100,000, and the nitrogen as nitrates below 0·2 of a part.

Clay waters are, as a rule, opaque, from a variable quantity of suspended matter, but generally there are few dissolved solids, and the water is fairly soft. They vary, however, greatly in their composition. The waters collected from cultivated land present great variations in composition, and the total hardness may range from 5 to 20 parts per 100,000, according as to whether the soil is non-calcareous or calcareous. Alluvium is generally a mixture of sand, clay, and organic matter; and waters from such a source generally contain high mineral solids (50 to 100 parts), consisting of calcium and magnesium salts, sodium chloride, iron, and silica, and also excess of organic matters.

2. *Waters from a Depth.*—Those collected from the chalk are generally clear, bright, and well charged with carbonic acid. The total solids are generally from 25 to 50 parts per 100,000, and the total hardness from 15 to 30 parts; the hardness is mostly temporary, and calcium carbonate may vary from 10 to 30 parts. The chlorine is commonly from 2 to 3 parts, but it may reach a higher figure in some pure chalk waters. The nitrogen as nitrates is below 0·5 part per 100,000, and is commonly about 0·3. Sulphates are present in small quantity, and there is often a trace of phosphates and of iron. Although the carbonic acid present is often sufficient to turn blue litmus red, when this is driven off an alkaline reaction is invariably obtained.

Some waters derived from the chalk are very soft and contain sodium carbonate. They are only found where the chalk lies buried beneath a thick mass of London clay (Thresh).

Waters from the oolite present characters very similar to those from the chalk.

Those derived from limestone and magnesian limestone formations only differ from the chalk waters in generally containing more total solids, far more calcium or magnesium sulphate (which may reach nearly 20 parts per 100,000), and less calcium or magnesium carbonate, and by consequence the hardness is generally higher and to a greater degree permanent.

In dolomite districts the mineral solids contain much magnesium carbonate and sulphate, and a large proportion of the total hardness is permanent, dolomite being a double carbonate of lime and magnesia.

The greensands are porous strata containing a reducing salt of iron, which by reducing oxidized nitrogen to ammonia often furnishes to the water a very high figure of free ammonia. The total solids vary considerably, but they sometimes approach 100 parts per 100,000 where the water is collected at great depths from greensand underlying the chalk; the chlorine may reach a figure of from 4 to 14 parts; the total hardness (much of which is permanent) is very variable—from a low to a high figure; and the nitrogen as nitrates is generally from about 0·3 to 0·6 part per 100,000.

Waters from red sandstone strata vary considerably in their composition, according as the deposit is pure or impure, soft or hard. The total solids and total hardness are both sometimes high, and the former may reach 100 parts per 100,000; the latter is mainly of a permanent nature, but the water may sometimes be soft and possess a total hardness figure not exceeding 10 parts per 100,000. The chlorine may vary from 2 to 6 parts per 100,000; and traces of phosphates are always to be detected in the mineral solids, which mainly consist of sodium chloride, carbonate and sulphate, calcium and magnesium carbonates and sulphates, and a trace of iron.

Waters from selenitic deposits are often harmful to drink, on account of the large proportion of calcium sulphate (10 to 30, or more, parts per 100,000), which is taken up from the deposit—this consisting of calcium sulphate in clear crystals.

Waters collected from loose sands are of variable composition. Some are soft, with total solids of from only 6 to 12 parts per 100,000, and others are rather hard (permanent), with mineral solids amounting to even 100 parts per 100,000. The chlorine figure is generally rather high, and may amount to a high figure in some cases. The mineral solids consist of sodium chloride, carbonate and sulphate, calcium and magnesium salts, and traces of iron and silica. Those from gravel are generally soft, but some are hard, with high total solids.

Waters coming from a depth in the lias clays have generally very high mineral solids (often consisting largely of calcium and magnesium sulphate). There is, as a rule, considerable opacity, and the physical characters generally are not favourable to the water. The hardness, which is almost entirely permanent, is generally over 20, and the mineral solids may reach 300 parts per 100,000.

Quantity.

The water supplied to a community must be good in quality and abundant in quantity. Impure waters are liable to cause injury to the health of those who drink them; whilst deficiency of water means want of cleanliness, with its ensuing discomforts and dangers.

Water is required for the following purposes, the under-mentioned quantities representing average requirements:—

		Gallons per head daily.
Household	Fluids as drink	0·33
	Cooking	0·75
	Personal ablution	5·00
	Utensil and house washing	3·00
	Clothes washing (laundry)	3·00
	Water closets	5·00
Trade and Manufacturing		5·00
Municipal	Cleansing streets Public baths and fountains Flushing and cleansing sewers Extinguishing fires	5·00
Total		27·08

The quantities of water given above as required for the household are those which are necessary to maintain a good condition of cleanliness. The 5 gallons for personal ablutions would allow a daily sponge bath for each person. If each person has also a weekly general bath of from 30 to 40 gallons, 5 gallons extra per head daily must be added.

In towns, 5 gallons per head daily is found to be ordinarily sufficient for municipal purposes; and the same amount is required, on the average, for manufacturing and trade purposes. Water is also required for animals—drinking, washing, and cleansing of stables. About 16 gallons daily for each horse, and 10 gallons for every cow, are average requirements.

On the whole, it may be said that not less than 30 gallons per head of the population should be supplied to every town daily. There will always be some waste in households from leaky taps and fittings, and this must be provided for. The greater part of the waste, however, very often takes place from the mains, before the water reaches the consumer. In some towns it has been found that as much as one-half or two-thirds of the total water supply has leaked out of the mains into the soil. The supplies per head in the various towns in this country vary greatly.

In villages where the water is carried by hand from wells and there are few w.c.'s and baths, the consumption may fall below 8 gallons per head per diem.

The amount of water actually utilized in the houses of a town varies enormously. In the houses of the poor it may be only 2 or 3 gallons per head daily; whereas it should amount to at least 15. The adult human being consumes daily about 2½ pints of water as drink, and about another 2 pints in his solid food.

Distribution.

The system adopted by the ancient Romans for conducting the water collected at the gathering grounds into their cities was the construction of masonry aqueducts built on arches, with a gentle incline to allow of a steady flow of water from its source to its outflow in the city. The aqueducts usually crossed the valleys on raised arches, but the Romans also knew how to construct inverted siphons of lead piping for the passage of the water across valleys. The remains of the reservoirs with which the inverted siphons were connected on either side of a valley are still to be seen in the neighbourhood of Lyons.

The water supplied by public companies to towns in this country is now usually distributed from their reservoirs through iron pipes laid underground. These cast-iron mains are subject to much rusting and corrosion, especially when the water is soft. Many of these pipes have been found much weakened by corrosion at some places, and nearly blocked with accumulated rust at others, the water also having deteriorated in quality. It is now usual to coat these pipes with some material which is unacted on by water, such as Angus Smith's solution,[1] or with a vitreous glaze. The magnetic oxide of iron produced on the surface of the metal by Barff's process is also occasionally used. In this process the iron pipes are heated to a white heat, and then exposed to superheated steam for several hours. The practice of caulking the joints of iron pipes with tow or gaskin next the interior of the pipe, and then running the joint with molten lead, was strongly condemned by the Rivers Pollution Commissioners, as the water absorbs impurities from the tow and hemp. They recommended that the pipes should have

[1] Angus Smith's process consists in heating the pipes to a high temperature and then dipping them into a hot varnish consisting of coal-tar pitch, resin, and linseed oil.

turned and bored joints, or, in the case of mains large enough for a man to enter, that the inside of the joint should be pointed with Portland cement. The mains should have scouring valves at their dead ends, and should be placed at a minimum depth of 3 feet, so as to be protected from frost and sun. All the service pipes of the house must also be protected from extremes of temperature, but they should always be left accessible; and if concealment is necessary, it should only be by a removable wooden casing. On freezing, water expands, and the pipe may burst; but as the fracture is not discovered until the thaw sets in, there is a popular impression that the thaw is the cause of the pipe bursting.

An enormous amount of leakage formerly took place from water mains in many towns, from slight settling of the ground after laying, or from the vibration of heavy traffic causing fracture of the pipes and joints. The loss is especially great where the supply is constant and the mains always kept under pressure. If the spots at which leakage occurs could be known, the pipes could be easily taken up and repaired, but the difficulty is to find where the leaks are. This difficulty has been overcome by Mr. Deacon, who has invented a meter which can be used as a waste detector. One of these meters is placed on each district main; it registers the flow of water by day and night and therefore the waste, for the water flowing through the main during the dead of night is not used by the consumers, but is running to waste. Having localized the waste to the district supplied by a district main, the exact spots where the leakages are taking place can be determined by the vibrations thereby produced in the nearest house communication pipes, which can be distinctly heard on applying a stethoscope to the pipe.

The temperature of the water in the underground mains of a town varies considerably with the season of the year. In Chelsea, where the temperature of the water in the mains was tested daily for some years, a minimum temperature of from 37° F. to 40° F. is usually recorded in January or February, whilst a maximum of from 68° F. to 74° F. is usually attained in July or August. The water temperature follows the mean air temperature, but the changes are of course far less in volume, and are effected more gradually. It would seem probable that the temperature of the water in cisterns exposed to the sun and atmosphere is likely to be considerably in excess of that drawn

from the mains during the warm months of the year, so that temperatures of 80° F. are probably not unusual under such conditions.

The house communication pipes in nearly all towns are of lead connected with the main by a brass screwed ferrule. Lead house service pipes are employed, because the ductile metal can be easily bent as occasion may require in carrying the pipes through a house, and they are easily jointed and rustless. If wrought-iron pipes are used, double screw joints should be provided at convenient points to admit of the clearing away of the rust, which often chokes an unprotected iron service pipe. Lead pipes may be acted on by water, especially soft water with an acid reaction, and in this way there may be danger to the consumers. Such has not been found generally to be the case, for although new lead pipes are undoubtedly acted on by soft water, an oxide of lead being formed which rapidly dissolves again in the presence of faint acidity, the action is often very slight. The Loch Katrine water acts most powerfully on lead, and yet no symptoms of lead-poisoning have ever been observed amongst the population of Glasgow. It is now recognized that the degree of plumbo-solvency of a water is chiefly determined by the amount of its acidity, and that this acidity is mainly due to acid-producing bacteria in peat. A distinction must be made between plumbo-solvency and the "erosion" of lead surfaces which sometimes takes place; the latter depends on the presence of dissolved oxygen, and shows itself by the formation of a relatively insoluble powder (the oxy-hydrate of lead), which may tend to fall away from the surface, and so permit of progressive action.

The hard waters, which contain salts of lime and magnesia, either have very little solvent action on lead, or they quickly coat the metal with the basic carbonate or sulphate of lead, which prevents further action. The soft, highly oxygenated waters containing organic matters, peaty acids, nitrites, nitrates, and chlorides, are those which have the most powerful action on lead, the oxide of lead which forms upon the surface of the metal being constantly dissolved and carried away in the water. Where lead-poisoning is feared, a block-tin pipe or a cast or wrought-iron pipe protected by a coating of Angus Smith's solution should be substituted for the lead pipe. Block-tin pipes enclosed in lead pipes are occasionally used; it is important

that there should be no crack or fracture of the tin lining, otherwise galvanic action will be set up when the pipe is full of water and large quantities of lead will be dissolved. Great care, moreover, is necessary in making the joints on this kind of piping, as the heat necessary for making a joint in the lead pipe is liable to melt the tin. To obviate this a layer of asbestos is sometimes introduced between the lead and tin, this serving to keep the metals apart. Polluted shallow well waters have sometimes been known to have a very powerful and persistent solvent action on lead, probably from their containing excess of carbonic acid, which tends to dissolve the coating of carbonate of lead formed in the pipe or cistern.

It has been suggested that the varying powers of corroding lead, exhibited by soft waters of apparently identical chemical composition, are influenced by the presence or absence of silica in the water. When silica is present, even in the proportion of only half a grain per gallon, the action on lead is said to be very slight. There must be no excess of alkali in the water, or this inhibitive action of silica is not displayed. By passing distilled waters and other soft waters known to have a corrosive action on lead through a filter formed of layers of sand and broken limestone, enough silica is taken up to reduce the lead corrosive power very considerably. Recent experiment, however, seems to show that the alkaline carbonate, which may be taken up from the limestone, may be an even more important factor than the silica. The waters of several large towns, which have a considerable effect on new lead, have been rendered nearly inactive by neutralizing the acid present by a solution of sodium carbonate or by slaked lime. The solvent properties of these waters are believed to be mainly due to the presence of peaty acids (humic, ulmic, etc.), and if the acidity is thus neutralized the plumbo-solvent action of the water is much reduced. After the prolonged drought of 1887, the waters in the Sheffield reservoirs ran very low, the peaty acids—derived from the gathering-grounds—were not diluted to the usual extent, and a severe outbreak of lead-poisoning occurred in the town. In rare cases the acidity which gives the water its lead-dissolving powers may be due to the presence of free sulphuric acid formed by oxidation of iron pyrites, when the water drains off rocks rich in that substance. It was suggested by Power, in a report to the Local Government Board, that the biological characteristics of

a water—the presence or absence of bacterial organisms—may exercise an influence over its "plumbo-solvent" properties; but this is probably true only in so far as the production of acidity in peaty matter is the result of micro-organic life.

Having regard to the importance of acidity as affecting plumbo-solvency, on some gathering-grounds measures are taken to divert the most acid feeders of the general upland surface supply, and so avoid the inclusion of the more plumbo-solvent waters in the general supply. There is also some evidence to show that leaden pipes are much more rapidly corroded when the mains are intermittently charged, than when kept under constant high pressure.

Water companies supply water to their customers either on the constant or the intermittent system. Under the former, the aim is to keep the mains constantly charged with water under pressure, so that the house pipes being also always charged, no storage of water on the premises of the consumer is required. The only cisterns which should be required in a house supplied with a constant service of water are small cisterns or water-waste preventers for flushing water-closets, and a small cistern to supply water to the kitchen boiler. Under the intermittent system, the flow of water in the mains is stopped, except for a short period of every day, by the turncock. The house pipes are only charged when the water is flowing in the main, and consequently water must be stored for use on the premises when the pipes are empty.

The great fault of the *intermittent service* is that water must be stored on the premises of the consumer. Water stored in small receptacles, even under the most favourable circumstances, deteriorates; it loses its aerated character, may become flat and insipid, and collects impurities from the air. In the houses of the poor, water is often stored in the most filthy receptacles—wooden butts and tubs, rotten and decayed within, or cisterns exposed to the air, which are the receptacles of all sorts of filth and rubbish. The situations in which cisterns are often found on such property are the immediate vicinity of the w.c., and beneath landing floors, staircases, or even bedroom floors. Even in the better-class houses cisterns are sometimes placed in the most improper places, as under stairs or floors, where dust and dirt fall into them, or inside water-closets, where the air is at times charged with foul gases.

Another disadvantage of the intermittent service is that the capacity of the cistern is often utterly inadequate—especially in tenement houses, occupied by numerous poor families—for the wants of the people who depend upon it as their only source of supply. Moreover, the intermittent charging favours corrosion of the service pipes.

The same cistern is far too frequently used to flush water-closets as well as to supply the drinking water, which may become polluted in this way (*see* Chapter II).

Another method by which drinking water in cisterns becomes liable to pollution is the practice—now, fortunately, but seldom seen—of connecting the "standing waste," or overflow pipe of a cistern with a drain or soil pipe of the house, or with a D trap under a water-closet (*see* Chapter II). The overflow pipe from the cistern should discharge in the open air as a warning pipe—at some point where it is not exposed to polluted air.

Besides the danger of pollution of water in cisterns by sewer air, dust, soot, and accidental contaminations such as dead mice, birds, or cockroaches, the material of which the cistern is composed is an important factor as regards the purity of the water stored in it. Iron cisterns rust and discolour the water; zinc is occasionally dissolved in small quantities by water; lead is dissolved at first when the cistern is new, but rapidly becomes coated with carbonate or sulphate of lead when the water is hard. The deposit forms a lining which protects the surface of the metal from further action, and it is for this reason that the inside of a leaden cistern should never be scraped when the cistern is being cleaned out. A lead cistern may be protected against the action of soft water by coating it with lime from time to time. Galvanized iron is largely used for cisterns; it is light, cheap, and durable, and generally perfectly safe, but may give up zinc to the water. In galvanizing iron, the metal is first washed in a weak solution of vitriol and cleansed and dried; it is then placed in a vessel containing molten zinc, which adheres to it and forms a coating. Wrought-iron cisterns covered with a vitreous enamel may also be safely used. Slate, though heavy, is a good material for cisterns, but the cemented joints of the five slabs must not be repaired with red lead when they leak, as they often do; for both white lead (a mixture of carbonate and oxide) and red lead (an oxide) are soluble in water. Glazed or vitrified stoneware and fireclay cisterns,

though heavy, are very valuable, as they give up nothing to water, and no joints are necessary. In selecting them, however, care should be taken that the enamelling or glazing is not rough or fractured. Enamelled iron, glass-lined iron, and tinned copper cisterns have been made. Water should never be left in contact with wood, as wood, when constantly wet, rapidly rots, and forms a breeding place for minute worms and other animal organisms and fungi.

To indicate briefly the conditions under which water may be safely stored in houses:—(*a*) The cistern should be of stoneware, slate, or galvanized iron; (*b*) it should be placed in a light and well-ventilated position, and should be properly covered; (*c*) it must not be used to flush water-closets, but may supply the "intercepting" or waste-preventing cisterns which should be used for this purpose; (*d*) the overflow pipe must be carried out into the open air to terminate as a warning pipe; (*e*) the cistern should be cleaned out at least once in every three months, and should be reasonably accessible for this purpose.

Cisterns are occasionally used to supply water-closets which have regulator valves on the supply pipes near to the closet basin. Although there is but little danger by this arrangement of foul air finding its way into the drinking water of the cistern, as the supply pipe is always full of water unless the cistern is empty, still, it is better to break the connection altogether between drinking water cisterns and water-closets.

The advantages of an intermittent over a constant service are that there is less waste inside houses, and that the service of pipes, taps, and fittings need not be so strong as for a constant service. This latter point has been disputed, as regards the pipes, on the ground that there is a greater strain on the pipes where the water is suddenly turned on or off with a common stop-cock, than where it is slowly turned on or off by the screw-down tap used with a constant service; but it must be remembered that with a constant service the water in the house pipes is under a much higher pressure than where the pipes are connected with a cistern in the house. There is less danger, also, with an intermittent service, of the higher parts of the town being without water on account of great waste in the low-lying parts, as sometimes occurs with a constant service.

A merit often claimed for the *constant service* is that no storage is required on the premises of the consumer. The water drawn

from the taps on the house pipes is clear, cool, and sparkling, in the same condition as it leaves the street mains, and the supply is—or should be—abundant and never-failing. But experience has shown that it is generally desirable to retain or provide some means of storing water on the premises, to meet requirements when the supply is cut off on account of repairs to the main or by frost.

In houses supplied by a constant service it is a good plan to obtain a direct supply for drinking purposes from a draw-off tap fixed on the service pipe on its way to the cistern, when the latter is retained as a means of storage.

It has been suggested that the shape of the cistern in common use should be modified to that of a cylinder, ending below in an inverted cone, with a draw-off pipe at its bottom to admit of the flushing away of any deposit which accumulates; the service pipe from the cistern to be soldered into the side like the present overflow pipe, but of course lower down, and the lid to be tightly fitting.

In actual practice in many cases, the advantages of a constant service have been somewhat mitigated by errors on the part of both consumers and water companies. Unless constant inspection is exercised and the taps and fittings in houses frequently supervised, there is great waste. This occurs especially in cases where an intermittent service has been changed to a constant service, and the old pipes and fittings have been retained. Not only this, but where water-closets are flushed by a pipe and tap direct from the house main, without the intervention of a cistern or water-waste preventer—a not unusual occurrence in poor neighbourhoods—there is great danger of foul air, or even liquid filth, being sucked up into the empty pipe when the tap is left unscrewed, and so finding its way into the water main of a district. The suction is due to a partial vacuum being created in the water mains when the water is turned off, owing to the water finding its way through leaky joints into the soil, or from the mains being emptied by taps on house pipes at a lower level. Such occurrences are believed to have given rise to outbreaks of enteric fever at Croydon, Cambridge (Caius College), Sherborne, and other places. They demonstrate the absolute necessity of breaking the connection between water-closets and water mains by the interposition of a small cistern or water-waste preventer.

In some cases of constant service, water companies try to economize by insisting on the insertion of a throttle of very small diameter ($\frac{1}{8}$ to $\frac{1}{16}$ inch) into the house communication pipe, with the result that water merely dribbles out of the house taps when they are full on. In any case, screw-down taps must be substituted for common taps, and a screw-cock must be placed on the house pipe, where it enters the premises, to shut off the water in case of a pipe bursting. A drip-tap should also be placed on a pipe at the lowest part of the system, by which it may be emptied during frost. All the leaden service pipes of a house should be strong (12 pounds per lineal yard for 1-inch pipes, and 6 pounds per lineal yard for $\frac{1}{2}$-inch pipes), in order to withstand the constant pressure to which they are subjected. If pressure is maintained in the mains by pumping, and not by storage in a high-level reservoir, greater power must be used in the morning of every day, this being the time when the largest quantities of water are drawn for domestic use. The waste of water can be overcome by the use of Deacon's waste-water meter on the district mains, and by frequent supervision of house taps and fittings. The supply of water by meter would tend greatly to check waste, but is not advisable in the case of poor populations, as the inevitable stinting of water that would follow would have great sanitary disadvantages. For trade purposes it is the most just and reasonable method. Water meters are either "positive," and indicate the amount of water supplied by the number of times a cylinder of known capacity is filled, as shown on a dial; or they are "inferential," when the amount of water which has passed through them is inferred from the velocity of the flow, as registered on a dial.

There is one danger to which water mains are subject, which has not yet been alluded to. If water mains and sewers or house drains are laid in the same trench, there is a possibility of foul matters, which have escaped into the soil from leaky drains or sewers, being sucked into the water mains if these are in any way defective, during intermissions in the service. Such intermissions are the daily occurrences of an intermittent service, and are often unavoidable with a constant service for executing necessary repairs to the pipes. In a similar manner, too, water mains may suck in from the surrounding soil coal gas which has escaped from leaky gas pipes and mains. It is not only, however, during intermissions in the service that

such accidents may occur, for experiments prove that there is a partial vacuum inside water pipes in the immediate neighbourhood of defective joints, whenever the water is flowing in the pipes. The water and sewerage systems must be kept as far apart as possible. Rats have been known to burrow from a drain or sewer to an underground water supply in search of water, lead water pipes being frequently found gnawed, and sometimes perforated.

With a constant service the mains are always charged in case of fire; with an intermittent service much valuable time is often lost in finding the turncock.

Purification of Water.

While the dangers from specific micro-organisms may be largely, if not entirely, removed by adequate storage and sand filtration, it is highly desirable that the water supply of a community should, as far as possible, be kept free from all foreign and polluting ingredients. Nearly all waters derived from natural sources contain such ingredients, and the various processes of purification aim at their elimination. The foreign ingredients may be divided broadly into mineral and organic matters. The removal of the salts producing hardness and the production of softer water is eminently desirable for economic purposes, and occasionally to improve the potability and wholesomeness of the water when the salts are in great excess. The removal of the organic matters, suspended or dissolved in water, is another and still more important object in any process aiming at complete purification. We shall now proceed, first, to the consideration of those processes which are, or could be, undertaken on a large scale for the purification of water before its distribution to the consumers; and, secondly, to such processes of domestic purification as may be undertaken on his own premises by the consumer.

What should be aimed at, however, is to procure at its source a water sufficiently good to require no artificial purification; but failing this, the water should be efficiently purified before its distribution to the consumers. It is certainly not wise to leave the purification to individual initiative.

Purification on a Large Scale.—There are several processes (Clark's, Porter-Clark's, Maignen's, Howatson's, etc.) which aim

at the removal of the mineral matters (the salts of lime and magnesia) from a water. The fundamental basis of them all is the addition of lime water. When a certain quantity of lime water is thoroughly mixed with a hard water, it combines with the carbonic acid holding the chalk in solution, with the result that the new carbonate thus formed is precipitated, together with the original chalk. In this way chalk well waters of 20° of hardness, and Thames water (16°), may be reduced to 4° or 5°. The hardness thus got rid of is due to the precipitation of chalk, and chalk alone; it is temporary hardness, and the same effect would be produced on the water by sufficient boiling.

The working of the process (Clark's) may be described shortly as follows:—One ounce of quicklime to every 700 gallons of water is used for each degree of temporary hardness. The lime in the form of quicklime is first slaked with water in a tank, into which the water to be softened is gradually allowed to flow; thorough mixing must be insured by wooden paddles or other mechanical means. The water becomes milky in appearance from precipitation of the chalk, and must then be allowed to settle for twelve hours, the supernatant clear water being subsequently drawn off. Besides chalk, a certain amount of colouring and organic matters are removed from the water by this process. It is important that uncombined lime should not pass out with the purified water, as would be the case if lime were added in excess of that required to combine with all the carbonic acid holding the chalk in solution. To detect uncombined lime, it is only necessary to add a few drops of a solution of nitrate of silver to the treated water in a shallow white dish, when a brownish colour is produced if uncombined lime is present, but only a white precipitate of chloride of silver if there is none present.

Lime is also used as the precipitating agent in Porter-Clark's process; but the suspended particles of chalk are removed, not by settlement, but by filtration through a series of linen cloths in a filter press under high pressure. The plant includes two vertical cylinders and a filter press. In the first cylinder there is a continuous preparation of lime water, which is mixed in the second cylinder with the hard water. The precipitant formed is then separated by the press. The process is expeditious, and very effective in removing lime and suspended

matters from the water. It is one of the best means of softening water on a large scale.

In Atkins's process, which is somewhat similar, arrangements are made for cleansing the cloth filters by means of revolving brushes which play on the surface of the discs.

The Stanhope Water Softener aims at reducing both the temporary and permanent hardness, lime and soda being used. The caustic soda somewhat reduces the permanent hardness by converting some of the calcic or magnesic sulphates into sulphate of soda. Clarification is effected by subsidence in high tanks containing numerous funnel-like shelves, one above the other, which collect the deposit and direct it to the bottom of the tank.

Howatson's process is very similar. In this process the deposit is removed by opening valves in the hopper bottoms of the tanks.

In the Maignen Automatic Softener a small motor is worked by the water, and this regulates the amount of *anticalcaire*, which mixes with the water in a small tank. Sedimentation takes place in a second small tank, in which provision is made for flushing out the deposited chalk; and finally the water passes through a *filtre rapide* into a storage tank. The precipitating agent, *anticalcaire*, contains lime, sodium carbonate, and alum. A small plant suitable for use in a dwelling house is also made.

The Lawrence process of softening and sterilizing water is ingenious and effective. In this apparatus the water is boiled, and therefore softened and sterilized; the steam is condensed by the cold water entering the boiler, which takes up the heat from the steam, and thereby an important economy is effected in the heat required.

The "Permutit" system of water softening is of service for domestic purposes. Permutit is a compound of silica and alumina with various bases, its essential property being that known as "base-exchange." In contact with hard water, for example, "soda-permutit" effects an exchange of bases, the hard water becoming soft because the permutit gives up its soda and takes to itself the calcium and magnesium bases. The action is perfectly automatic; and when the soda-permutit is exhausted regeneration may be effected by passing through the permutit column some 10 per cent. salt solution, when the calcium and magnesium are eliminated as chlorides, and reformed soda-

permutit is ready again for the treatment of more hard water. This method is capable of reducing a water of a high degree of hardness to one showing little or no hardness. Manganese-permutit is effective for removing iron from water.

The Sterilization of Water on a Large Scale.—There are three processes, now actually available, by which water can be sterilized on a large scale, namely (1) chlorination, (2) ozonization, and (3) the action of ultra-violet rays.

(1) *Chlorination.*—A water of fair chemical purity and free from suspended matter can be sterilized effectually—certainly as regards *B. coli* and other organisms of intestinal type—by the addition of bleaching powder or a solution of hypochlorite of calcium, sodium, or magnesium, or by chlorine (either gaseous or liquefied), so that there is maintained in the water 1 part per million of available chlorine for about half an hour. The carbonic acid naturally present in the water liberates hypochlorous acid from the hypochlorite of calcium, etc.

Bleaching powder is quite convenient to use. When fresh it furnishes about 33 per cent. of free chlorine, but deteriorates if it is not protected from the air. The deterioration of bleaching powder in tropical countries is due to the interaction of the bleach and its absorbed water under the influence of heat; it has been found that it is practically impossible to obtain an anhydrous bleach on a commercial scale. The difficulty has been overcome by adding 20 per cent. of quicklime, and it has been found that tins of this bleach and quicklime mixture, after several months of storage in the tropics, show very little fall in the available chlorine content. The minimum amount necessary to be employed (thus avoiding the need for subsequently removing residual chlorine) may be ascertained by testing a water on the lines suggested by Sir William Horrocks. The water having been clarified, if necessary, is treated as follows:—

A standard solution of bleaching powder (one drop of which added to a small measure of water is calculated to represent one part of chlorine per million of water) is first prepared. A series of such measured volumes of water is then treated with a varying number of drops of this standard solution (beginning with one drop for the first measure, and working up to 6 drops in the sixth measure). At the end of half an hour 3 drops of zinc iodide and starch solution are added to all six measures, and the measure which furnishes a blue colour with these reagents with the fewest number of drops of the standard solution furnishes a clue to the minimum amount of chlorine necessary for that particular water.

By such minimum treatment the taste of the water is almost natural. The bleaching powder is changed into harmless calcium carbonate and calcium chloride.

The chlorination of water has been found very effective in controlling epidemics of enteric fever, as at Lincoln in 1905, where the town water supply was polluted. Not only was the water supply sterilized, but the water mains and pipes through which polluted water had passed were rendered non-infective by this process. By the method employed, however, not only were comparatively large amounts of chlorine added to the water (1 in 50,000 at Lincoln), but chlorine was still present in the water as supplied to the consumer, giving the water a very disagreeable taste and flavour

In a permanent chlorination installation it is necessary to remove the residual chlorine before the water enters the mains to supply the consumers. This can be done by means of thiosulphate of soda, but is now more effectually accomplished by passing the sterilized water through filters containing vegetable charcoal, which absorb the residual chlorine, and remove all odour and taste from the chlorinated water. If the water can be allowed to stand in an open tank for four hours there will generally be no complaint as to taste; and this can also be removed, in many cases, if the water is made very faintly pink by the addition of permanganate.

The chlorination process is very much less costly than treatment by sand filters, and, if properly carried out, offers a surer guarantee of the removal of all deleterious organisms than any system of sand filtration, unless the water has been previously stored foı three or four weeks in storage reservoirs and thoroughly sedimented. It is especially applicable in the case of river waters, which are liable at times to sewage contamination. If the water is at all turbid, it should be clarified by filtration through small beds of sand or polarite prior to chlorination.

The mixing of the hypochlorite solution with the water is best effected in a hopper tank of known capacity, the hypochlorite in measured volume being placed in the tank prior to the entrance of the water. The inward rush of the water effectually mixes the hypochlorite solution with the water to be acted upon, and, after standing at rest for half an hour, the sterilized water is evacuated from the tank and filtered through a layer of granite chips, and then through charcoal for the removal of any free

chlorine. *B. coli* should invariably be absent from the water so treated in 100 c.c.

If the treatment has to be continued for any length of time, however, an improvement on this method is to provide a small tank to hold the chlorine solution, which is fed from a larger tank, and kept filled to a certain level by means of a ball tap or other similar contrivance. In this way a constant level, and therefore constant pressure, is maintained in the small tank, which assists in regulating the flow. If this is fitted with a fine glass tube, having a controlling tap and a pressure gauge, the solution may be allowed to drip at such a rate as to pass the required amount per hour into the water, the rate of discharge of which into the reservoir is known. The tap should be so arranged as to drip over the point of discharge of the water into the reservoir.

When the chlorine cannot be added to the water in the reservoir, the solution may be injected into the rising or other main by means of a suitable contrivance, such as a pump driven by a turbine from the rising main.

If the water is very impure, discoloured, or contains much suspended matter, it should, if circumstances permit, first be clarified by the addition of from 2 to 8 grains per gallon of alum and an equal proportion of powdered whiting, and allowed to stand in a tank, from which it should be decanted to another tank for the addition of the chloride of lime solution.

The chlorination process has already been adopted largely in the United States for town supplies, and is now coming into use in this country by the Metropolitan Water Board and other water authorities and companies. It was the method adopted by the military authorities, both at home and abroad, for the purification of water for the troops during the Great War.

(2) *Ozonization.*—This process has been tried on the Continent with success, but has not been much taken up in this country. The electrical installation for the generation of ozone gas in quantities sufficient to sterilize large volumes of water is both expensive and complicated, and the treated water has a disagreeable taste until it has been allowed to stand for a considerable time.

Ozonized air is produced by ozonizers—appliances in which silent electrical discharges are made to pass through a space $\frac{1}{16}$ inch wide between glass and aluminium cylinders (Siemens de Frise type). Air enters at the bottom of the ozonizers,

traverses the space where the silent discharges are occurring, and issues at the top charged with ozone. This ozonized air is introduced into the water to be treated through an injector into a pipe conveying the water, and the mixed air and water then pass into the bottom of a tall cylinder or sterilizing tower, divided at regular intervals by horizontal diaphragms consisting of perforated celluloid trays, whereby the ascending currents of gas and water are intimately mixed. The volume of ozonized air should be about 40 per cent. of the volume of water to be treated. The water issues at the top of the sterilizing tower, and is received into an open enamelled iron collecting tank. In the de Frise process, of which the above is a description, at the St. Maur Municipal Waterworks, Paris, oxides of nitrogen, peroxide of hydrogen, and chlorine were not found in the treated water by Rideal (*Journal of the Royal Sanitary Institute*, January, 1909).

Some of the ozone in the water attacks and destroys organic matter, and some passes again into the air at the top of the sterilizing tower, and can be here recovered and returned to the ozonizers. Some remains in the water, but disappears in the course of an hour or two. Ozonization destroys all but the more resistant spore forms of water bacteria present. *B. coli* and allied intestinal organisms are entirely eliminated. Unless the water is of distinctly good quality chemically, a previous filtration is necessary, otherwise all the ozone may be used up in oxidizing organic matter, and the germicidal action is rendered ineffective.

(3) *The Ultra-Violet Rays.*—Experiments conducted by Miguel showed that in *clear* and *bright* water *B. coli* is killed in from 15 to 20 seconds by exposure to the ultra-violet rays proceeding from a mercury vapour lamp. *B. typhosus* is killed in from 10 to 20 seconds, and the *Cholera vibrio* in from 10 to 15 seconds. The water must be bright and clear, without trace of suspended matter, and the thickness of the film of water penetrated by the light must be small.

The mercury arc vapour lamp used in this installation is enclosed in a tube of fused rock crystal or transparent quartz, which permits the passage of the ultra-violet rays of the source of illumination, glass being a complete absorber of these rays. The mercury is vaporized by the passage of an electric current. The lamp is placed in a special cast-iron chamber, divided into

compartments by diaphragms, which cause the water to be treated to pass in close contact with the quartz tube. The time of exposure to the light should be sufficient to destroy all organisms of intestinal type. An automatic deviating valve should be fitted to the apparatus, to insure that no water passes through the sterilizing chamber when the lamp is not in operation.

The process has the advantage over chlorine and ozone that nothing of a chemical nature is added to the water, and that sterilization is insured if the bacterial contents of the water are known, and the time of exposure to the rays thereby adjusted. On the other hand, turbidity of the water, or the presence of colloidal matter, seriously interferes with sterilization, as the microbes are sheltered from the action of the rays by such material; and, in addition, the deposit of a brownish sediment from the water on the transparent quartz tube, which occurs sooner or later with all waters, diminishes in corresponding degree the effectiveness of the rays; whilst the liability to cracking of the quartz, owing to the high temperature of the lamp, and the coldness of the water passing over it, adds considerably to the cost of upkeep of the installation.

In recent installations, the apparatus has been so constructed as to provide that the water, while passing as close as possible to the lamp, shall be separated from it by an air space. The amount of ultra-violet ray radiation in this improved apparatus is ten times as great as in a lamp immersed in water.

(4) For the copper treatment of water vide p. 56.

The Purification of the Water of Swimming Baths.—The water of swimming baths which are frequented daily by many bathers becomes highly charged with bacterial organisms derived from the bodies of the bathers. Organisms are present which are derived from the mouth, nose, and throat, and also from the intestinal and urinary tracts. When highly diluted and intermixed with large volumes of clean water, these possibly harmful organisms, even when swallowed by bathers, are probably too few in number to originate disease. Still, infection may at times occur, when the bath has been used by persons in an infective condition; and it is important that swimming should at all times be carried on under conditions as little likely to favour the transmission of infection as possible. Infections of the nose, throat, and middle ear, sometimes inducing fatal meningitis, are believed to be not very uncommonly the result of the use of

swimming baths where the water is not sufficiently or frequently renewed. The warm months at the height of the bathing season are the most dangerous, and the young are most affected.

The simplest method of putting this in practice is to change the water frequently—daily, if possible; but this usually involves a heavy cost. Continuous aeration and filtration plants for swimming baths have been devised, by which the used water can be submitted to a certain amount of purification, and so prevent the necessity for constant change of water.

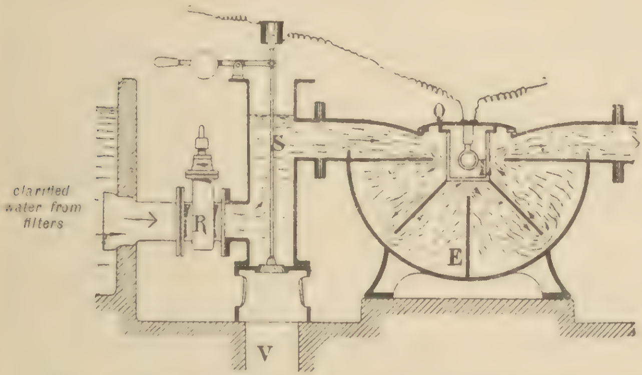

FIG. 9.—MERCURIAL VAPOUR LAMP FOR STERILIZING WATER.

E, sterilizing chamber, with baffles for directing the flow of water; *L*, lamp-box fitted with three windows of cut rock crystal; *O*, wing-nuts for securing box; *R*, supply valve to apparatus; *V*, deviation valve connected with solenoid (*S*), which is energized by the current to the lamp. Should the current be cut off, the valve opens, and the water ceases to pass to the sterilizing chamber.

A Committee of the Royal Sanitary Institute (February, 1913) investigated this matter, and reported that such plants are effective to a certain extent in preventing the higher grades of bacterial pollution, and in maintaining the water fairly clear and free from odour. The water is not, however, sterilized, nor is it kept free from the slimy matters which tend to accumulate on the walls and floors of the bath. On the other hand, by the addition of "electrolytic fluid" (a very weak solution of hypochlorite of magnesium, prepared by the electrolysis of water containing certain definite proportions of sodium and magnesium chloride) to the bath water in amount sufficient to give one part of free chlorine to every one or two million parts of water, not only is the water sterilized, but it is kept sweet

and free from odour, and there is no tendency to the deposition of slimy sediments. Water containing this proportion of free chlorine is probably freed from infective organisms in sufficient degree to prevent danger to bathers. Chlorinated disinfectants, containing definite proportions of free or available chlorine, may be used instead of "electrolytic fluid," which involves the installation of a generating plant.

Domestic Purification.—*Distillation* effects a more complete purification of water than any other method which is practised. If the first portions of the distillate, containing volatile substances present in the water to be distilled, are rejected, a water free from all foreign ingredients is obtained. Its aeration, however, is deficient; but this aerated quality can easily be furnished by allowing the water to flow out of fine holes in the bottom of a receptacle and to pass through the air in finely divided streams. The distillation of sea water is now largely carried out on board the ships of H.M. Navy and in the large steamships of the mercantile marine. As long as there is fuel on board, a most wholesome water can be obtained. Distilled water acts very readily on metals such as copper, zinc, iron, and lead; so it is important that the several parts of the distillation or condensing apparatus should not expose these metals to the action of the water. Silver-lined or block-tin vessels and pipes may be used. There are now several makes of small domestic stills upon the market.

By *boiling* water, carbonic acid is driven off with other volatile gases dissolved in the water, and chalk (temporary hardness) is deposited at the bottom of the vessel. The water is therefore softened. We have the strongest reason for believing that distillation and boiling—raising the temperature of the water to 212° F.—render innocuous all organized living matter in the water. There can be little doubt that the germs of cholera, enteric fever, and of other diseases, occasionally propagated by means of impure drinking water, are effectually destroyed by even a few minutes' boiling. The spores that resist the temperature of boiling water are, seemingly, not disease germs, but merely the immature forms of harmless species; for experience has shown that water, and other fluids mixed with water, such as milk, in which the existence of germs capable of producing enteric fever, cholera, scarlet fever, or diphtheria, was almost undoubted, have been rendered harmless by a few minutes' boiling.

But to sterilize completely water or any other fluid, it is

necessary to boil it, or merely raise the fluid to a temperature of 212° F. without actual ebullition, for a short period (half an hour) on three or four successive days. In this way the spores which escape destruction by the first boiling have time to develop into adult bacteria, which are destroyed by the next boiling, and so on, until all the successive crops are disposed of. Boiled water is flat and insipid, and should be aerated before being drunk.

The Waterhouse-Forbes is perhaps the simplest form of portable apparatus for boiling drinking water, such as is required for the use of armies in the field.

Various *chemical* schemes have been suggested for the domestic purification of water. Such a method made easily practicable is of great value for military purposes to meet the requirements of troops on the march, or in the field, when the adequate filtration or sterilization of sufficient water for drinking purposes is a matter of great difficulty. Schumberg's bromine process consists in adding 0·06 grain of free bromine, dissolved in potassium bromide, to every litre of water, and then after 5 to 10 minutes removing the excess of bromine and making palatable by sodium sulphite and carbonate. The addition of calcium peroxide, of ozone, and of potassium permanganate, have been suggested by other authorities, but have been little employed. Chlorine in the form of a hypochlorite, or as hypochlorous acid obtained by the electrolytic treatment of salt water, is also serviceable for the above-mentioned purposes. Bleaching powder has also been employed for the purpose of sterilizing water. When this powder is added to water the hypochlorite of calcium which is liberated is acted upon by carbonic acid, and splits up into carbonate of calcium and hypochlorous acid, the latter being a powerful oxidizing agent. Ozone is more expensive and difficult to employ than chlorine, and organic matter in water may give rise to an unpleasant odour after the use of either of these sterilizing agents.

The use of acid sodium bisulphate has been recommended by Parkes and Rideal in the proportion of one gramme of the salt to a pint of water, experiment having shown that in this strength, if contact is permitted for fifteen minutes, *Bacillus typhosus* infection in broth culture medium is destroyed. In Nesfield's method a 2-grain tablet of iodide-iodate of soda and a similar amount of citric acid are added to 4 gallons of water, the effect being to kill

in a few minutes any typhoid and cholera organisms that are present. Subsequently the free iodine may be eliminated by a tablet of sodium hyposulphite. The poisonous effect of copper upon the lower forms of life has led to its advocacy and adoption for the purpose of removing certain growths which form odour in stagnant water, and also specifie micro-organisms. There is, for instance, testimony to the fact that the addition of 10 pounds of sulphate of copper to 1,000,000 gallons of water was sufficient to remove a fishy odour which was previously in the water. There is also evidence that the addition of sulphate of copper, in the proportion of 1 part to 100,000 parts of water, will destroy the typhoid bacillus; but there is conflict of opinion as to whether this is always effective in 24 hours. Strips of copper foil immersed in water for 12 hours will generally destroy the typhoid bacillus; and this is also true of the storage of water in copper vessels. In many waters most of the copper is deposited in an insoluble form; but before this method of treating water can be safely advocated it is necessary to study the further effects of very small quantities of this metal upon the more susceptible human beings.

Alum is sometimes employed as a purifying agent. It is much used in China, where the turbid waters of the large rivers are extensively drunk after the addition of a little alum. When added to water containing chalk in solution, it forms a bulky precipitate of aluminium hydrate, which falls to the bottom, carrying with it suspended and floating matters. It has little or no effect on organic matters in solution in the water. About 6 grains of alum to the gallon of water is the proportion generally required.

Filters.—Domestic filters are probably more often a source of pollution of the water than otherwise. It is usually considered that a filter requires no attention; it is consequently but rarely cleaned; the filtering material is seldom renewed, and its pores become clogged with putrescible organic matters, which form a suitable nidus for the growth and development of living organisms which contaminate the filtered water. It is not unusual, under such circumstances, to find a considerably larger proportion of organic matter in the filtered water than was present before filtration.

This is especially the case when *animal charcoal* is used as the filtering matenial. This substance is prepared by calcining

crushed bones in closed vessels; it is extremely porous, and exerts considerable oxidizing action on dissolved organic matters in water, and bleaches colouring matters in solution. These properties, however, are evanescent, and rapidly disappear if the charcoal is not cleaned or renewed, especially if the water filtered through it is somewhat impure. Not only this, but the charcoal yields to water phosphate of lime, of which it is largely composed. The phosphate favours the growth of living organisms, so that water must neither be kept too long in the filter, nor should it be stored for use after filtration. Charcoal block filters have the power of removing lead from water if their surfaces are kept constantly clean by frequent scrubbings; this is probably due to the lead forming a phosphate in the filter.

Silicated carbon and *manganous carbon* block filters are frequently used. They consist of animal charcoal compressed into blocks by admixture with silica or manganese. They do not yield so much phosphate of lime to water as the pure animal charcoal filters, but they tend to become coated with a layer of organic matter which clogs the pores. The block should be brushed occasionally to remove the thin film coating it; and every three months, at least, it should be purified by subjecting it to a red heat, or by boiling it in a solution of Condy's fluid and sulphuric acid. *Maignen's Filtre Rapide* consists of a strainer of asbestos cloth spread over a perforated porcelain cone. Powdered animal charcoal, or other filtering medium, is laid over the strainer. The delivery of water through this filter is very rapid, and the asbestos and powder can be easily renewed at a very small cost.

Domestic filters are also made of *spongy iron, magnetic carbide of iron, polarite,* and *carferal,* this latter substance being a mixture of iron, charcoal, and clay. It has good oxidizing properties, and yields nothing to water which is favourable to organic life; but its lasting powers are inferior to spongy iron and magnetic oxide and carbide.

In Bischoff's spongy iron filter the iron ore rests upon a layer of pyrolusite (a crude oxide of manganese) above, and a layer of fine sand below. The pyrolusite acts as an oxidizer, and helps with the sand to remove the iron taken up by the water. The outlet to the filtered water receptacle is generally protected by a layer of asbestos cloth.

Filters of the kind alluded to above may be required to cleanse

a dirty water, or to prepare a water with fine suspended matter in it for passage through a germ filter; but they afford no protection against the infection of water-borne disease. Sir Sims Woodhead and Dr. Wood pointed out that they may materially increase the risk to the consumer of acquiring such infective diseases, inasmuch as the specific organisms of these diseases become arrested in the filtering materials, and may then be washed through in great numbers into the filtered water for many days subsequent to the introduction of infected water into the filter. If, for instance, the water supply of a house received a chance contamination, which rendered it dangerous for one day only, the consumption of the water involves the risk of specific infection on that day only; but should the polluted water be passed through a domestic filter of the kind indicated, the arrest of the specific microbes in the filter, and their subsequent passage into the filtrate, would render the water passed through the filter liable to convey infection for several days after the initial introduction of the pollution. The consequent multiplication of the opportunities of infection necessarily greatly increases the risk of such an occurrence. The wrong and misleading statements set forth so prominently by the makers of such filters, as to their capacity to render any water, however polluted, harmless and innocuous, gave rise to a false sense of security in the minds of the public, and are an evil which should be strenuously combated.

In the *Pasteur-Chamberland* filter the water, under pressure, is passed through hollow cylinders of a specially prepared form of porous porcelain. The filtered water is entirely free from all suspended matters, including all kinds of organisms and their spores. The water is therefore sterilized; but, the filter acting merely mechanically, there is no alteration in the chemical composition of the dissolved constituents of the water. This filter is employed to sterilize pure waters for laboratory purposes, and may with advantage be so used for domestic purposes. The bottom of the filter is connected with a main under pressure, the water issuing from the top. These filters require periodical cleaning every few days by a hard brush, to remove slimy deposits on the surface of the porcelain; if this is not done, the delivery of water becomes very much reduced, and separated organisms may in time grow through the cylinders.

The *Berkefeld* filter is similar in principle to the above, but the hollow cylinder, through which the water is filtered is

composed of a compressed siliceous or diatomaceous earth called Kiesselguhr (fig. 10). It permits of more perfect cleansing and is very much more rapid in its delivery, but is more fragile than the Pasteur-Chamberland filter.

The experiments of Woodhead and Wood show that the Berkefeld table filter completely arrests specific disease organisms, but that, like the Pasteur-Chamberland, the Slack and Brownlow, and the Porcelaine D'Amiante to a lesser degree, it allows water organisms usually present in water to grow through the filtering material, with the result that they appear in the filtrate on the third day after introduction. It does not, therefore, continuously sterilize. The Porcelaine D'Amiante filter, in which the clay is mixed with finely powdered asbestos, is the best sterilizer, but in it the rate of filtration is so slow that it is unfitted for domestic purposes.

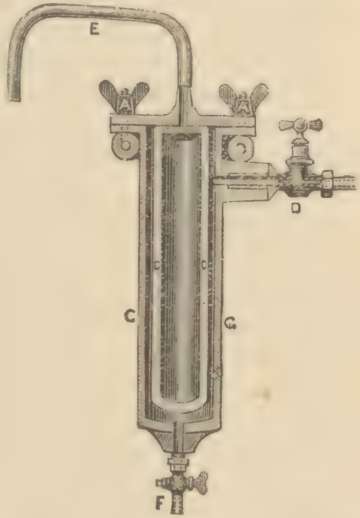

FIG. 10.—BERKEFELD FILTER.

AA, screws, for joint to open filter case for removing filtering cylinder for cleaning, etc.; E, outlet for filtered water, which can either be fixed or simply placed on the protruding metal end of the cylinder; CC, filtering cylinder; D, tap union to attach to water service; F, flushing tap to wash out filter or to supply unfiltered water.

The experiments conducted by Sir William Horrocks at Netley in 1901 show, (1) that typhoid bacilli are not able to grow through the walls of the Pasteur-Chamberland candle; and the filter ought to give complete protection from water-borne enteric fever. (2) Typhoid bacilli can grow through the walls of the Berkefeld candles, probably owing to the larger size of the lacunar spaces, and the consequently diminished immobilizing and devitalizing influences. The time required for the typhoid bacilli to traverse a candle varies between 4 and 11 days, and appears to be largely dependent on the nutriment supplied to the organisms by the medium in which they exist. In order to obtain complete protection from water-borne enteric fever, when employing Berkefeld filters, it is

necessary to sterilize the candles in boiling water every third day.

It is obvious that the substances of which this class of filters are composed must be quite free from flaws, otherwise a direct passage of micro-organisms will take place. There is also a certain amount of liability to failure owing to hidden defects in the connection made between the sterilizing candle and the delivery pipe.

Sometimes the only water available for drinking, in addition to the risk of its being specifically infected, also contains much suspended matter. It is useless to attempt to filter such a water through porcelain, as the filtering material soon becomes clogged. The Brownlow germ filter, in which the water is first passed through charcoal, and then through porous porcelain, is specially advantageous in such cases; or the porcelain may be covered with a strainer of fine linen cloth, which can easily be renewed.

Filters should never be placed inside cisterns. In such positions they are neglected, their very existence being sometimes forgotten, with the result that they become excessively foul and pollute the water they are intended to purify.

From what has already been said, it will be seen that the essentials of a good filter are—that every part should be easily accessible for cleansing purposes; that there should be nothing in the construction of the filter which is capable of yielding metallic or other impurities to the water; that the filtering medium should be efficient for the work in hand, and its purifying power reasonably lasting; and that the delivery of filtered water should be reasonably rapid.

Diseases produced by Impure Water.

Dyspepsia and Diarrhœa.—Waters with permanent hardness exceeding 8° or 9° sometimes cause dyspeptic symptoms and diarrhœa, especially amongst those who are not used to them. Similar symptoms are generally produced by drinking brackish water drawn from wells near the sea coast. The injurious salts are especially the sulphates of magnesium, calcium and sodium, and the chloride of magnesium. Particles of suspended clay, mica, or vegetable matter may also cause diarrhœa.

Waters containing calcium carbonate in solution, the temporarily hard waters, are not in any way injurious to health. At the same time there is no reason to believe that the chalk

waters are at all superior to soft waters for drinking. The idea once entertained, that the salts in hard water aided the growth and nutrition of the bones in children, has been abandoned as untenable.

Diarrhœa, often of a severe choleraic type with headache, purging, vomiting and cramps, is occasionally produced by drinking water contaminated with sewage. But here, again, it is principally amongst those who are unaccustomed to the water that these severe symptoms occur; or when the water, previously fairly pure, becomes temporarily polluted. Several outbreaks from this cause have been reported in this country. Instances have been known where people have gone on drinking filthily polluted shallow well water for years with no apparent bad effects. It seems, indeed, certain that by long habitude the system becomes tolerant of many substances in water which exert a marked effect on those who drink them for the first time. Whether the choleraic diarrhœa is due to the presence of a living germ in the water, to fæcal organic matter in solution or suspension, or to alkaloidal poisons, the products of the growth of bacterial organisms, is not yet certain.

Vegetable matter, such as peat in water, is generally harmless. Large excess of such matters, especially when decaying, may produce unpleasant symptoms.

Infantile diarrhœa, which is so prevalent and fatal in the large towns of this country in the warmer summer months, appears to be due to water pollution in some cases.

The same conditions of drinking water which produce diarrhœa in this country often give rise to *dysentery* in hot climates. Dysentery may certainly be spread by the evacuations of patients suffering from this disease contaminating the water used for drinking.

Enteric Fever and *Paratyphoid Fever* are sometimes spread by the medium of water. There is considerable evidence of the possibility of discharges of a single patient infecting large volumes of water (*see* Chapter IX).

Asiatic Cholera is a specific disease, spread by a specific virus contained in the evacuations of a person ill of the disease. There is now abundant evidence that cholera is often propagated by means of drinking water to which the specific disease poison has had access. This is not the only mode of spread of the disease, any more than it is of enteric fever; but the evidence which is

constantly accumulating points strongly to the conclusion that as for enteric fever, so for cholera—specifically infected drinking water is one of the most frequent methods of its propagation.

Urinary calculi were at one time supposed to arise from the use of hard water, but this view is now generally abandoned from want of any definite proof.

Rickets has been ascribed to the use of soft water, but the contention is not warranted by facts.

Goitre appears to be due, in many instances, to the water used for drinking, but the impurities in the water which appear to favour hypertrophy of the thyroid gland in some districts are not those found in the water of other goitrous districts. For instance, the carbonates and sulphates of lime and magnesia, which are present in the waters of some districts, and have been credited with being the cause of goitre, are not found in the waters of other districts where goitre prevails. The presence of sulphides of iron or copper in water has been regarded by some observers as the cause of goitre, but not apparently with much reason.

Major McCarrison, I.M.S. (Milroy Lectures, 1913), as the result of a very exhaustive investigation of the etiology of endemic goitre in India and elsewhere, is of opinion that the essential cause of the disease is a micro-organism that obtains admission to the intestines of man, and there creates a toxin, which so influences the thyroid gland that it undergoes enlargement, the function of the thyroid being the production of antibodies or antidotes to poisonous products produced in the living body and circulating in the blood. The special micro-organism, as yet unidentified, appears to be present in the soils of goitrous districts, and to be thence conveyed to man in water, which passes through or over the goitriginous soil. The ideal conditions for the development of endemic goitre are stated by McCarrison to be a country district with an agricultural population living on a porous soil, which soil contains much organic matter, and which by virtue of its porosity or slope admits of the ready passage of organic matter into the unprotected streams and wells that are the water supply of the people. It is in mountainous districts where limestone rocks abound that these conditions are most frequently found in combination; consequently, goitre is pre-eminently a disease of the hills.

Entozoa.—The embryos or eggs of the following parasites have been found in water, and may be taken into the stomach

of man when such water is used for drinking. They are: *Tænia solium*, *Tænia echinococcus*, *Bothriocephalus latus*, *Ascaris lumbricoides* (round worms), *Oxyuris vermicularis* (thread worms), *Filaria sanguinis hominis* (tropical endemic chyluria)—the embryos of which are sucked from the blood of infected persons by mosquitoes, and, after developing in the body of that insect, are then transferred to water by means of the larvæ—*Bilharzia hæmatobia*, *Trichocephalus dispar*, and *Distoma hepaticum* (liver fluke of sheep). *Bilharzia hæmatobia* causes endemic hæmaturia in Egypt, Abyssinia, the Cape, etc. The ova are passed with the urine, find their way into water, and hatch into ciliated embryos. *Anchylostoma duodenale* causes anæmia, internal hæmorrhages, etc., and occasions great mortality in Brazil, West Indies, and Egypt, where it is thought to be sometimes due to infected water. The embryo guinea worm, *Filaria dracunculus*, is aquatic and finds its way into the human body through the alimentary canal by means of drinking water, the adult worm being subsequently found in most cases in the subcutaneous tissue of the feet and legs of affected persons. Aquatic *leeches* may be swallowed in the act of drinking, and fixing themselves in the pharynx may cause much hæmorrhage. Anthrax, hog-cholera, and glanders may all be communicated to cattle through the agency of impure water; and drinking water appears to be the principal medium by which the entozoa generally pass from one animal to another.

Metallic poisoning may be caused by pollution of drinking water with refuse from trades and drainage from metalliferous mines, or from absorption by water of the metals used in the construction of distributing pipes, tanks, and cisterns. The amounts of copper, zinc, or arsenic which must be present in the water to give rise to symptoms of poisoning have not been definitely ascertained; as regards lead, as little as $\frac{1}{10}$ grain per gallon may produce plumbism in predisposed persons. In the case of the poisoning of Louis Philippe's family at Claremont, $\frac{7}{10}$ grain of lead was found in each gallon of water.

The Collection of Samples of Water.

The water should be sent to the analyst in a stoppered Winchester bottle holding about half a gallon. The bottles should be reserved for water samples, and should be cleansed

with strong acid, and subsequently well washed with clean water, before use. The bottle should be rinsed out twice with some of the water to be examined, and should not be entirely filled with the sample, a small amount of air being left in it. The bottle should then be stoppered and capped with clean wash-leather or linen, and dated and labelled to enable subsequent identification. Where the sample must be taken by immersing the bottle, as in ponds, reservoirs, rivers, and open wells, the bottle invented by Dr. Thresh, which contains a contrivance whereby water can be made to enter the bottle at any required depth from the surface, finds a useful application.

The Opinion upon a Water Sample.

Where the water is considerably polluted, no difficulty is experienced in detecting the pollution by chemical analysis; but, generally speaking, the slighter degrees of pollution are detected only with difficulty.

The most a chemical analysis of a water can tell us is whether the figures of the analysis indicate little or much organic impurity as judged from certain arbitrary standards. Whether the slight contamination which is practically always discovered is harmful, or whether the particular water has recently received slight (but significant and maybe dangerous) pollution, can only be told with certainty by several analyses of the water at short intervals of time, and a careful comparison of the results obtained; or by a comparison between the sample of water and others in the immediate neighbourhood, collected from similar sources from the same geological area, and which are known to be above suspicion. A chemical analysis, in short, cannot always guarantee absolute purity and safety, but it very frequently serves to reveal impurity and danger.

Nitrates and Nitrites.—These are the oxidized residues of organic matters, almost always derived from an animal source (sewage). Their determination is, therefore, a point of the greatest importance, for they indicate either a pollution of the water at some remote period with possibly dangerous ingredients, or the contamination of the water at the present time with partially or completely purified sewage. They are found, often in considerable quantities, in deep wells or spring waters, and in this case merely indicate the complete purification which

the water has undergone in its passage from the surface to the subterranean reservoirs. In the case of shallow-well waters, nitrates and nitrites, if found in association with excess of chlorine and ammonia, indicate soakage into the well of sewage or animal refuse more or less purified by its passage through the intervening layers of earth. At any time, however, the purifying power of the filtering earth may be exceeded or overcome, and then the liquid filth may pass into the well with its dangerous ingredients unchanged or unpurified. Nitrates and nitrites are not present in raw sewage, but they are found in polluted streams and watercourses, where a certain amount of oxidation is always in progress, and in the effluent subsoil waters from manured or sewaged land.

Ammonia.—The urea of the urine, by a process of fermentative decomposition, rapidly becomes carbonate of ammonia in sewage. Ammonia will therefore be found in all sewage-polluted waters, unless the sewage has been filtered through a sufficient thickness of soil to enable the bacteria to convert the ammonia by oxidation into nitrates and nitrites. A few pure deep-well waters from the greensand are found to contain excess of ammonia owing to the presence of a reducing salt of iron, which converts oxidized nitrogen into ammonia; but these waters are remarkably free from organic matters. On the other hand, sewage-polluted shallow-well waters, which contain excess of ammonia, often contain also an excessive amount of organic matters.

Organic matters derived from an animal source are dangerous as well as disgusting; the slightest trace of such matters in a water should suffice to condemn it. Organic matters derived from the vegetable world, though often quite harmless, as when they exist in the form of peat, should not be disregarded; and their presence in considerable quantity should insure the rejection of the water for drinking purposes.

The distinction between animal and vegetable organic matters in a water is often only made with difficulty, if at all. Generally it may be said that, when excess of organic matter in a water co-exists with excessive chlorine, oxidized nitrogen, and ammonia, the source of pollution is animal filth or sewage. When, on the other hand, excessive organic matter is not accompanied by excessive chlorine, oxidized nitrogen, and ammonia, the source of pollution is probably vegetable; and this diagnosis may be

confirmed by the results of physical examination of the water, and by microscopic examination of the suspended matters and sediment.

Inasmuch as the chemical methods of analysis can only determine the presence and amount of organic matters in water, and cannot determine their quality, nor separate living and possibly actively dangerous organisms from dead and inactive matter, it has been thought by many that the bacterioscopic examination would afford conclusive evidence of the possibly dangerous qualities of a water, and might come in time to supersede chemical analysis altogether.

But the specific micro-organisms of typhoid fever are only with great difficulty isolated from the crowds of harmless species which are generally found in great abundance where water is contaminated with human excrement. The finding of a greater or less number of non-pathogenic bacteria or fungi in a water gives evidence of the presence of a larger or smaller amount of organic pollution, which forms a suitable pabulum for bacteria; for pure waters are found to contain very few bacteria or fungi, whilst impure waters often swarm with them. They increase in numbers if water is stored for any length of time

The detection of bacteria of intestinal type, which have their usual habitat in the intestines of man and animals, throws considerable light on the nature of the pollution, and if they are present in such amount as to point to recent contamination, should serve to secure the condemnation of the water. The more important of these intestinal organisms, for which the tests have been most fully elaborated, are *Bacillus coli communis* and its congeners, *Bacillus enteritidis sporogenes*, and *streptococci*. A water which gives no indications of the presence of typical *B. coli communis* in 10 c.c. of the water examined, nor of *streptococci* in 50 c.c. (?), nor of the spores of *B. enteritidis sporogenes* in 500 c.c. is, at the time of the examination, so free from sewage pollution that it may be certified as safe for all domestic purposes providing its source is satisfactory (Thresh).

By the typical *B. coli communis* is meant the organism found in animal excrement and in fresh sewage. It would appear that in water to which this organism has obtained access, the typical *B. coli* undergo after a time changes of a degenerative character, so that they no longer fulfil all the tests which are characteristic of the typical organism. There are also other

organisms of intestinal type, such as *B. acidi lactici* and *B. enteritidis* (Gaertner), which give most of the reactions of *B. coli*, but not all. It is doubtful, at present, as to what is the precise significance of the presence of such organisms in water. Their presence certainly should lead to suspicion and to further investigation, as they may indicate a recent previous sewage contamination, a contamination which may also be a recurring one.

The mere presence of typical *B. coli communis* and of *B. enteritidis sporogenes* in a water would not justify, on this ground alone, the condemnation of the water; for they do not necessarily indicate *human* contamination. It is only when the *B. coli* is appreciably present in 1 c.c. of the water that, in the opinion of many, the water should be regarded as definitely unsafe.

The *Bacillus typhosus* is exceedingly difficult to detect in sewage-polluted waters. It is very doubtful if this organism has ever been isolated from a natural water, even although such a water has been credited with the causation of enteric fever.

In addition to a chemical and biological examination of a water sample, it is of great advantage to possess the fullest information as to the risks of pollution to which the water has been subjected, and this can only be obtained from a painstaking local investigation.

ANALYTICAL RESULTS OF CERTAIN WATERS (PARTS PER 100,000).

	London Supply from New River (Filtered).	Polluted Well Water.	Peaty Surface Water.	Spring Water from Chalk.	Rain Water.	A Suspicious Water.
Total solids	31·2	60·0	10·0	33·0	3·0	40·0
(*a*) Volatile.. ..	9·8	25·0	7·0	10·0	1·5	15·0
(*b*) Non-volatile ..	21·4	35·0	3·0	23·0	1·5	25·0
Total hardness ..	21·5	30·0	5·0	26·0	0·5	25·0
(*a*) Temporary ..	13·0	15·0	1·0	20·0	0·0	14·5
(*b*) Permanent ..	8·5	15·0	4·0	6·0	0·5	10·5
Chlorine	1·8	7·0	0·7	2·5	0·25	4·0
Oxidized nitrogen ..	0·18	0·80	0·01	0·30	0·01	0·50
Free and saline NH^3	0·001	0·030	0·001	0·001	0·015	0·006
Organic NH^3 ..	0·003	0·015	0·018	0·003	0·000	0·012
Oxygen absorbed in two hours at 80° F.	0·030	0·160	0·200	0·030	0·015	0·120

CHAPTER II

THE COLLECTION, REMOVAL, AND DISPOSAL OF EXCRETAL AND OTHER REFUSE

In any community of persons, arrangements must be made for the collection and removal of their excretal refuse (fæces and urine), of the waste waters from houses, and of the dry refuse (ashes, dust, and refuse food). The solid and liquid refuse matters from stables, cowsheds and slaughter-houses, street sweepings, and the waste waters from works and manufactories, must also be removed.

In all towns the collection and removal of dung, ashes, dust, refuse food, and street sweepings is performed by mechanical labour, the various processes above mentioned being included in the term *scavenging ;* whilst in some, human fæces and a certain amount of urine are also removed by this method, after being deposited in privies, cesspools or dry closets, on what is known as the *conservancy system.* In a large majority of the towns of this country, at the present time, human excrement is removed with the liquid refuse of dwellings on what is known as the *water-carriage system*—a system of drains and sewers for the passage of the refuse in a liquid condition to some spot outside the town.

The public health largely depends on the efficiency with which refuse matters, and especially human excretal refuse, are removed from towns; for the health of towns in this country and abroad has very much improved, and the death rates have been permanently lowered, as the result of works of sewerage.

Removal of Domestic Dry Refuse.

Domestic dry refuse consists partly of mineral matters, but to a considerable extent of organic substances derived from the waste scraps of food, etc. These latter, being prone to undergo decomposition when stored in dust-bins or other receptacles, are very liable to become a source of nuisance. It is, therefore, very

desirable that the quantity of organic refuse to be temporarily stored on the house premises should be reduced as far as possible; and this may be accomplished by burning the more easily destructible matters, such as potato peelings and other food scraps, in the kitchen fire at the end of every day.

The old-fashioned brick dust-bin is now being largely replaced by galvanized iron receptacles, with well-fitting metallic covers, to insure dryness of the contents and their protection from rain. This is an important point, as the presence of moisture hastens putrefaction and the formation of offensive gases in the refuse. The non-absorbent walls of iron pails, and the ease with which they can be moved and carried out to the dust-carts, constitute very great advantages over the brick dust-bins, of which the walls become saturated with decaying matters and the contents are often incompletely removed at each visit of the scavengers. The contents of the dust-bins or pails should be removed at least once a week; in summer a more frequent removal is desirable, but is not usually practicable. Specially constructed carts provided with covers should be employed to convey household refuse through the streets. There is an obvious advantage in keeping the refuse as dry as possible, and if such vans are not provided with sliding metal covers or covers of tarpaulin, the escape of dust in windy weather creates a great nuisance. Motor dust vehicles are to be recommended as effecting a great saving of time.

Horse manure must also be frequently removed from stables, and the removal in urban districts is often attended with considerable nuisance, especially where peat moss litter is used as a bedding for the horses. The nuisance mainly arises at the time of loading the cart, in which the manure is removed, from the receptacle, the disturbance of the contents of the receptacle giving rise to very offensive gases; and the recently disturbed manure is often highly offensive as it is carted along public thoroughfares. It is found in practice that the best remedy for the nuisance is to store the manure in the same manure cart in which it is to be removed.

The disposal of house refuse has hitherto been mainly effected by depositing ("tipping") it on waste ground, the site being commonly called a "shoot." These refuse heaps frequently constitute a serious nuisance in the neighbourhood. Offensive gases are given off from the fermentation of the organic matters,

and the firing of the refuse; and the liquids draining from the heap are of the most noxious character, and occasionally cause serious pollution of neighbouring watercourses. In windy weather dust and the lighter particles are scattered around, whilst in summer the rotting refuse attracts large numbers of flies, which invade surrounding houses and settle on food exposed to the air. Rats, too, burrow in the heap in search of food, and are generally much complained of. The practice of shooting or tipping refuse cannot be defended, and it is slowly giving way to a more sanitary method, *i.e.*, the destruction of refuse by fire. As the area of a town increases, these muck-heaps often become the sites for buildings long before natural agencies have succeeded in purifying the "made-soil"; and, moreover, the difficulty of acquiring sites sufficiently near the area to be scavenged is growing greater year by year in our larger towns, and makes the adoption of some other method of house refuse disposal imperative.

The refuse, when deposited at the "shoot," is sometimes submitted to the process of hand-sorting. The paper and rags are removed for paper-making, the tins and iron for scrap, the bones for manure, the unbroken bottles for re-use, and the broken glass for re-melting. This sorting process is a degrading occupation; the workers are of necessity in a filthy condition, and the air they breathe is constantly polluted with fine dust and foul odours.

The best method of getting rid of dust-bin refuse is to burn it in a destructor furnace; and offensive market refuse, fish offal, and even diseased carcases can also be disposed of by this method without creating a nuisance. The proportion of cinders in the refuse is always sufficient to insure complete combustion in a well-constructed furnace. A small commercial value attaches to the residual clinker, either for making mortar, or mixed with granite chippings and cement to make paving slabs or concrete bricks. The temperature attained in the furnace, while destroying the refuse, can be utilized to generate steam for electric power to pump water or sewage, or to drive mortar mills. The calorific value of the screened house refuse varies from $\frac{1}{10}$ to $\frac{1}{5}$ that of coal. In summer the heat value of the refuse is least, owing to the smaller proportion of cinders and ashes and the greater quantity of garden refuse and vegetable matter.

There are various types of refuse destructors, most of which possess the following features in common:—The furnaces or cells are strongly built of brick with fire-brick lining, and the general

building is also of brick. The destructor is approached by an inclined roadway to the top or tipping platform, which is well above the ground level. In the centre of this platform is a series of feeding holes or hoppers into which the refuse is shot, and allowed to fall into the cells below. The stokers rake the refuse forward on to the fire; and after burning, the refuse is reduced to about one-third or one-fourth of its original weight, the residue consisting of fine ash, hard clinker, etc. By means of forced draught produced by a steam jet or fans, the combustion can be made so complete that temperatures of 1,500° to 2,000° F. are attainable merely from the burning of the refuse.

Some destructors are known as "slow combustion" or "low temperature" destructors, and in these "fume cremators" should be provided at the foot of the chimney. In the fume cremator (which is a coke furnace) incompletely burned vapours and fine dust particles, which are liable to escape into the air from the destructor furnace, are completely burned up before they can enter the chimney-flue. In the "high temperature" destructors such cremators are unnecessary, and the expense of burning the coke or coke-breeze in the fume cremator is saved.

The advantages of the "low temperature" destructors consist in the diminished wear and tear on the fire-brick sides of the cells, and the consequent saving in upkeep. On the other hand, the disadvantages are that both the inlet for refuse and the outlet for gases are, as a rule, at the rear of the cell, and therefore the empyreumatic and noxious vapours and fumes given off during the drying of the refuse, and before it is in active combustion, escape before being burnt, and a cremator is necessary. Further, more cells are required, because a smaller quantity of refuse per cell (from 6 to 8 tons) is burnt per day than with "high temperature" destructors. In the "high temperature" destructors (such as the Horsfall or the Beaman and Deas) the outlet for gases is at the front of the cell, and the vapours given off during the process of burning and drying pass over the hottest part of the fire to reach the exit. As the cell is raised to a very high temperature by forced draught (steam blast or fans), such gases are destroyed within the cell itself; a larger quantity of refuse is burnt per day per cell (*i.e.* from 10 to 16 tons), and fewer cells are therefore required. On the other hand, they cost more for maintenance.

The site on which the destructor is placed should be a central one for the district to be served, or the cost for cartage may considerably exceed that for burning; and in some cases it would appear advisable to construct two destructors in different parts of a large town.

The number of cells or furnaces required will of course depend on the nature and amount of the refuse to be destroyed, and also upon the type of cell adopted. If a "high temperature" destructor is selected, about ten cells are necessary for a population of 100,000. These cells can be erected in a single row or "back to back." The cost of erection may be taken as about £600 per cell, including enclosing building; and the burning will cost from 9*d.* to 2*s.* 6*d.* per ton, according to the greater or less completeness of combustion required, and the number of tons to be burnt per cell per day.

Another method of disposing of household refuse is to carry it out to sea in barges and there deposit it.

More recently a special method of sorting and screening the refuse is being advocated and adopted because of its economic advantages. The method involves a minimum of handling and no disagreeable work for those employed upon it. The plant consists of electrically driven revolving screens, which sort the refuse into constituent parts according to the size of the mesh of the screen. The first material sorted out is a fine dust, about 33 per cent. of the whole. This dust has a higher manurial value in nitrogen, phosphates, and lime than stable manure, and good reports have been received of it from agriculturists. The second material removed is a fine cinder which passes through a ½-inch mesh, amounting to about 26 per cent. of the refuse. This fine cinder when made into briquettes, with the addition of 8½ per cent. of pitch and ½ per cent. of tar, has a high calorific value. The third material is large cinder which, owing to its specific gravity, can be separated by a washing process from the heavier residue and has also a high calorific value. Its fuel value is 11, taking coal as 14. The large cinder constitutes about 18·5 per cent. of the whole. The heavy material which is separated by the washer amounts to about 14 per cent., and consists of stone, shale, broken pottery, while it also contains a certain amount of unburnt coal which falls out with the heavy debris. This heavy residue being washed forms a quite innocuous material for tipping. The vegetable matter, amounting to between 3 and 4 per cent., is burnt in the destructor or pulverized and added to the dust to increase its manurial value, provided a good market is found for the dust. The "tailings" or larger particles, containing tins (1 per cent.), rags (0·4 per cent.), paper (3·6 per cent.), are carried on to a revolving belt, where articles of value are picked off by hand. The tins are detinned in a furnace and pressed into bales, and find a ready market. The oily rags have the oil extracted, the dirty rags are sterilized, and a market is found for the clean remainder and the recovered oil.

Human Excreta.

An adult male, living on a mixed diet of animal and vegetable food, passes daily 4 ounces, by weight, of solid, and 50 fluid ounces of liquid excreta. The solid excreta of children under twelve years of age are in amount considerably less, probably on an average not much more than one-half the above quantities. If all ages and both sexes are considered, the daily amount of excreta per head of a mixed population may be taken at 2½ ounces of fæces, and 40 fluid ounces of urine. Fresh fæces contain on the average 23·4 per cent. of dry solids, and fresh urine contains 4·2 per cent. (of which 54 per cent. is urea).

The quantity of nitrogen voided per head daily in the excreta

of a mixed population is 189 grains in the urine and about 40 grains in the fæces, making a total of about 230 grains. The other valuable constituents of the excreta are phosphates and potash. A given weight of fæces is more valuable than the same weight of urine, in the proportion of about ten to six; but the weight of urine passed daily (in a mixed population) is about sixteen times as great as that of the fæces, consequently the total urine is worth about ten times as much as the total fæces.

Fæces and urine, especially when mixed, as in cesspools, privies, and sewers, rapidly undergo putrefactive changes, giving rise to the formation of fœtid gases (organic vapours, sulphuretted hydrogen, ammonium sulphide, etc.). The urea—$CO(NH_2)_2$—of the urine decomposes, giving rise to carbonate of ammonia—$CO(NH_2)_2 + 2H_2O = (NH_4)_2CO_3$—and so rapid is the change that it is probable that, even in the best-sewered town, all the urea of the urine in the sewage has been converted into ammonia before the arrival of the sewage at the outfall.

House Waste Waters.

In these are included the waste waters from kitchens, which are highly charged with decomposable organic matters and grease, and slop waters containing urine, soap, and the dirt from the surface of the body and from clothes. These waste waters, when mixed with the liquid refuse or drainage of stables, cowsheds, and slaughter-houses, with the washings from the street surfaces, with the urine from public urinals, and the waste liquors from manufactories, form the sewage of the non-water-closeted or midden towns. The drainage from stables is very rich in urine (one horse excretes about fifteen times as much urine as an adult man), and the waste liquors from manufactories are often excessively foul.

It is not surprising, then, to find that such sewage is often quite as foul as that of some water-closet towns, which contains the solid human excreta as well. The Rivers Pollution Commissioners stated in their First Report that, "for agricultural purposes, 10 tons of average water-closet sewage may, in round numbers, be taken to be equal to 12 tons of average privy sewage"—*i.e.* sewage of privy towns, where human fæcal matters are kept out of the sewers. Such being the case, it is necessary to bear in mind that, in towns where there are middens

or some form of dry closet for the collection of fæcal matters, there is also a liquid sewage to be conveyed away from houses by drains and from the towns by sewers, which is too impure to be admitted into a stream and which must therefore be purified before being discharged.

Conservancy Systems.

The Privy or Midden System.—The system which formerly prevailed in many towns in this country—where there was any system at all—was that of privies, midden pits, and cesspools, often open to the air and unprotected from rain, and situated in the yards and areas about houses. These receptacles were generally mere holes dug in the ground, and their contents overflowed, saturating the air with noxious effluvia, or percolated into the soil around and under the houses and poisoned the water in the neighbouring wells.

At the present time, in those towns which still retain conservancy systems, the privies are required to be constructed according to certain definite rules.

The model bye-laws of the Local Government Board with regard to the construction of privies and middens for new buildings require that the privy must be at least 6 feet away from any dwelling, and 40 or 50 feet away from any well, spring, or stream; means of access must be provided for the scavenger, so that the filth need not be carried through a dwelling; the privy must be roofed to keep out rain, and provided with ventilating openings as near the top as practicable; that part of the floor of the privy which is not under the seat must not be less than 6 inches above the level of the adjoining ground, must be flagged or paved with hard tiles, and must have an inclination towards the door of the privy of ½ inch to the foot; the capacity of the receptacle under the seat of the privy must not exceed 8 cubic feet—a weekly removal is then necessary; the floor of this receptacle must be in every part at least 3 inches above the level of the adjoining ground; the sides and floors of this receptacle must be constructed of impermeable material—they may be flagged or asphalted, or constructed of 9-inch brickwork rendered in cement; the seat may be hinged, or other means of access to the contents of the privy must be provided; and the receptacle must not communicate with any drain or sewer.

With privies constructed and managed according to these rules, there would be no danger of percolation of liquid filth into the soil around houses and in the neighbourhood of wells; and there would not be much pollution of the air from the

excreta—except during removal—if dryness were insured by the proper application to them of ashes and cinders. The success of the system depends to a large extent on efficient inspection by the sanitary inspector, and on proper scavenging arrangements.

Cesspools.—These receptacles for filth are so evidently undesirable in the neighbourhood of houses that it is the practice now in nearly all towns to fill them in, and provide more suitable means for the collection of excreta. When, in the year 1847, it became compulsory to carry house drains into sewers, many cesspools with which house drains were connected were filled up,

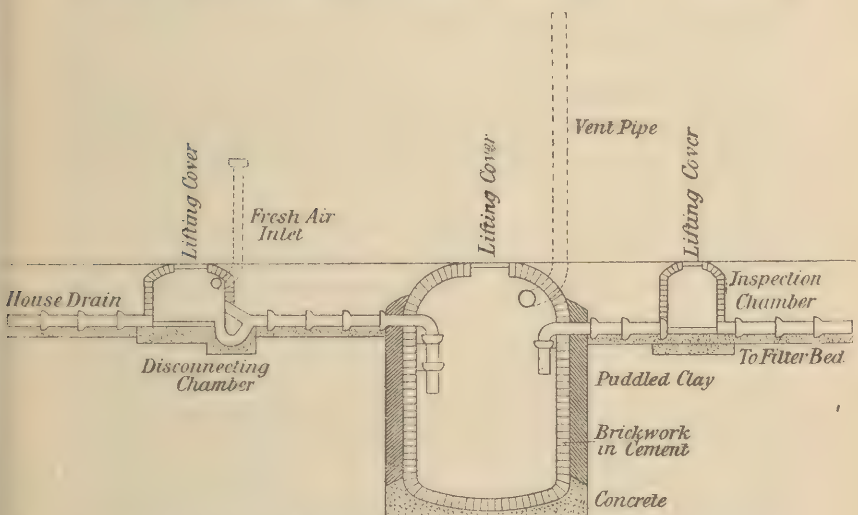

FIG. 11.—CESSPOOL WITH HOUSE DRAIN INLET AND OVERFLOW TO FILTER BED.

or otherwise abolished; but some of them escaped observation, and to the present day occasionally one or more cesspools are discovered in the basements of town houses, of the existence of which the owners or occupiers are ignorant.

In country districts where there are no sewers, cesspools are still largely used for the reception of human excreta and waste waters. When dug in a porous soil, such as gravel or chalk, they are too frequently constructed to allow all the liquid filth to percolate through their walls into the soil, with the certain danger of polluting wells, springs, and other sources of underground water supply. When the liquids escape thus easily,

the cesspool but very rarely requires emptying, and this fact constitutes the *raison d'être* of the porous cesspool.

The model bye-laws of the Local Government Board for new buildings require that a cesspool must be at least 50 feet away from a dwelling, and 60 to 80 feet distant from a well, spring, or stream. It must have no communication with a sewer (in sewered districts); its walls and floor must be constructed of good brickwork in cement, rendered inside with cement, and with a backing of at least 9 inches of well-puddled clay around and beneath the brickwork. The top of the cesspool must be arched over and means of ventilation provided. Constructed in accordance with these rules, and with the house drain disconnected from the cesspool in the same manner as it is disconnected from a sewer, the possible dangers of cesspools are reduced to a minimum.

In this country cesspools are often emptied by hand labour —a disgusting and dangerous task—or by pumping into a night-soil cart. On the Continent, and especially in Paris—where so many houses have a *fosse permanente* in the courtyard—the cesspools are emptied by pneumatic pressure. A flexible tube, connected with a tub or *tonneau* exhausted of air by an air-pump, is thrust down to the bottom of the cesspool. On turning a valve, the pressure of the atmosphere forces the contents up into the *tonneau*. The Bexley cart, now commonly used in this country, is worked on the same principle. This method does not give rise to any nuisance comparable with that from emptying the cesspools by hand labour. Whenever a cesspool or privy pit ceases to be used, it should be completely emptied and the contaminated brickwork, earth, etc., removed; or, after emptying, its walls should be well lined, and the interior filled up to the ground level with good concrete or with dry, clean earth or brick rubble.

The Pail System.—In this system the excreta are received into movable receptacles, such as pails and tubs. Removal is thereby greatly facilitated and there is no pollution of the air from disturbance of contents, as there always must be when the contents of middens are taken away. In some towns iron pails are used, in others tarred oak pails. The capacity of the pail should not be greater than 2 cubic feet. Both kinds should be provided with a close-fitting lid, to be adjusted before removal of the pail by the scavenger.

The structure of the privy (fig. 12) need only be very simple; it should be well roofed and louvred for ventilation, its floor being raised above the level of the ground adjoining and flagged,

and the pail placed under the seat. The seat may be hinged to insure a more complete covering of the excreta with cinders and ashes, when these are used, and to allow of the removal of the pail; or the back wall of the closet may be provided with a door to facilitate the latter purpose. The pail should be removed at no longer intervals than once a week and a clean one substituted.

It is very important, from a sanitary point of view, that the pail contents should be kept as dry as possible; and for this object the house ashes and cinders should be thrown into the pail, either by a scoop after each use of the closet, or by a mechanical arrangement (to be described under earth-closets) above the pail, which sifts the cinders and deposits the fine ash automatically on the pail contents, as in Morell's closet. All slops should be kept out of the pails, and should be carried away from the houses in drains with the other waste waters.

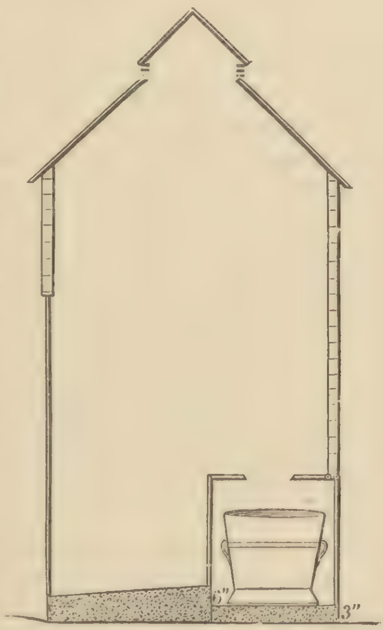

Fig. 12.—Privy constructed for Pail System.

The Dry Earth System.—This system, often referred to as Moule's system, consists in the application to the excreta, deposited in a pail or tub, of a certain quantity of dried and sifted earth. About one pound of dry earth applied in *detail*, i.e., each particular stool being covered at once with this quantity, is found to be sufficient to remove odour and to form a compost which remains inoffensive as long as it is dry. A certain action takes place in the mixture of earth and excrement, which results in the complete disintegration of the fæcal matters and paper, which after a time are found to have completely disappeared and are no longer recognizable. The compost after further drying may be used over again, and has the same action as the original dry earth.

The best kinds of earth are loamy surface soils, and vegetable mould. Sand, gravel, and chalk are unsuitable and inefficient.

The closet generally used with this system is almost identical with the cinder-sifting ash-closet previously mentioned. There is a hopper or metallic receptacle above and behind the seat, and the proper amount of dry earth is shot into the pail by a simple mechanical contrivance connected with a handle, or self-acting seat arrangement. The contents of the pail must be kept as dry as possible, or fermentation results, with the disengagement of foul gases; consequently slops must on no account be thrown into them, and even chamber urine must be kept out of them, unless a considerable extra quantity of dry earth is used. The earth must be dried before use, and then sifted by means of a sieve, the finer portions only being used.

Scavenging Schemes.—The wider adoption of scavenging schemes is a serious need for rural districts, and without them the pollution of the shallow wells must inevitably continue.

A scavenging scheme is most urgent where the cottages are in close juxtaposition, and possess only a very small garden area, and where the wells run exceptional risks of pollution. With a very small garden area, covered with a crop, the privy pit often cannot be cleaned out until the crop is taken out of the ground, and so pail closets requiring a weekly or twice weekly emptying are impracticable when there is no scavenging scheme.

Such a scheme adopted, it becomes possible to abolish all privy cesspits, and to replace them by pail closets on cemented surfaces.

A scavenging cart should be taken weekly to each dwelling; the pail contents and the dry domestic refuse (collected in covered galvanized iron pails) should be removed and sanitarily disposed of by a contractor. The special expenses chargeable to the parish are small for this kind of work, though they may be serious, having regard to the rateable value.

For emptying cesspools, the scavenging scheme should include a force pump and a hose, with a solution of copperas, to be employed when occasion demands.

The Disposal of Slop Waters.

We have already seen that the conservancy systems do not provide for the removal of the liquid refuse, domestic or municipal; and we have seen, too, that in the so-called midden

towns this liquid refuse or sewage may be quite as impure as the ordinary sewage of some water-closet towns. In these towns, too, there is always a certain percentage of houses provided with water-closets, so that the crude matter passing into the sewers is inadmissible into a river or stream, and requires to be purified. A system of drains and sewers is necessary for its removal from the town; and the principles on which such drains and sewers must be constructed do not differ from those which would be necessary if they were intended to carry water-closet sewage as well.

In small villages and isolated houses provided with middens or some form of dry closet, the slop waters are usually carried by a drain from a sink or yard gully into "sumpt" holes in the garden, into an open ditch, into a cesspool, or into a stream; if into a "sumpt" hole or open ditch, there to stagnate and generate offensive gases; if into a cesspool, often to percolate through its porous walls and pollute the neighbouring wells; and if into a stream, to foul it nearly as much as if they contained the solid excreta also. The slop waters may be retained in cesspools which are rendered impermeable by brickwork set in cement and well puddled with clay outside; and they can then be utilized on garden ground by means of a pump and hose and jet. They may also be passed through a small coke or ash filter, which should be prepared on a specially selected area well away from the house; or they may be disposed of by irrigation upon grass fields.

Wherever the nature of the soil and the slope of the land will permit of it, recourse may be had to *sub-irrigation* to purify the dirty water and utilize it to the best advantage. A very small piece of ground is required for this purpose. The late Mr. Rogers Field considered 4 perches of land sufficient for an ordinary cottage. The drain conveying the slop waters from the house should be connected by a few lengths of impermeable piping with a system of 3-inch agricultural porous earthenware pipes, without joints, laid laterally about 5 or 6 feet apart, at a depth of about 8 to 12 inches in the soil, the whole having a slight fall or inclination, away from the house, of 6 or 8 inches in 100 feet. The ends of the pipes should rest upon cradles formed of larger half-pipes, and similar covers should be placed above, so as to prevent earth getting into the pipes, whilst allowing the water to escape. The end of the main outlet pipe should turn up into the air to allow air to escape. This is especially necessary when the slop waters are discharged into the sub-irrigation drains by a flush tank.

If the soil is very porous, no under-drainage is needed; otherwise,

porous drain pipes must be laid at a depth of about 3 feet from the surface, with an outlet into a stream or ditch. The slop waters escape through the open joints of the sub-irrigation pipes into the soil, where some of their fertilizing ingredients are absorbed by the roots of the grasses and vegetables grown on the plot, and the rest is purified by percolation through the soil; so that the effluent water passes away in a purified condition into a stream or ditch, or helps to swell the volume of the subsoil water.

The chief difficulty in connection with this method is that the flow of slop water from a single house is so small that the liquid penetrates but a short way along the sub-irrigation pipes, which become in time choked with deposit; and that portion of the sub-irrigation plot nearest the house receives an unduly large share of the irrigating liquid, and its cleansing properties are speedily over-taxed. This difficulty, where the gradients admit of the necessary loss of head, has been overcome by providing a flush tank which will discharge at intervals into the head of the system. The tank now in most general use for this purpose is fitted with the annular siphon arrangement invented by Mr. Rogers Field.

In the annular siphon tank (fig. 13) the ascending arm of an ordinary siphon is represented by a short wide cylindrical pipe, closed at the top, which is placed over and encloses the descending arm, a longer pipe of smaller diameter. The upper end of the descending arm is open, and in Field's tank is provided with a lip projecting inwards and downwards, which serves to direct the water, as it overflows, into the centre of the pipe. The lower end of the descending arm opens over a discharging trough below the body of the tank, and is trapped by the water which stands in this trough to the level of the top of a weir, over which the water flows into a pipe connected with the head of the sub-irrigation system.

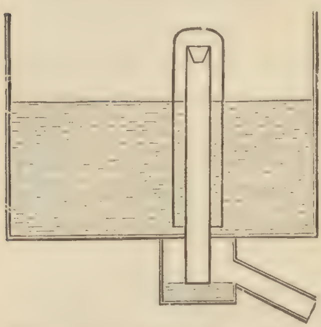

Fig. 13.—Field's Annular Siphon Flush Tank for Flushing House Drains.

Only a very small dribble of water into the tank is necessary to put the siphon into action. This takes place as follows: As the tank fills, the water ascends between the inner and outer pipes constituting the siphon, until it reaches the level of the top of the inner pipe, the air displaced finding an exit through this pipe into the discharging trough below. The water then trickles over the top of the inner pipe, and, thrown into its centre by the lip, falls clear of the sides, entangling and carrying air with it which cannot pass back, owing to the lower end of the pipe being trapped. This continues until the siphon is sufficiently exhausted of air to be brought into action, when the whole contents are discharged by siphonage.

It is not necessary to strain the slop waters before they enter the

tank, as they contain but few of the coarser suspended matters and solid particles found in water-closet sewage. The sub-irrigation drains require to be taken out of the ground, and the deposit removed before they are relaid, every few years, according to circumstances.

Comparison of Methods.

There can be no doubt that all conservancy systems proceed on a wrong principle, viz., that of keeping excremental matters within or near dwellings longer than is desirable from the point of view of health. In towns the expense of scavenging is directly proportional to the frequency of removal, so that there is always an inducement to the local authority to economize at the risk of the health of the inhabitants. The costs of this kind of scavenging are high, and nowhere does the sale of the refuse cover the expense.

Movable receptacles are far better than fixed ones for the collection of excremental matters. The pail system is undoubtedly the best for towns which will not enforce the adoption of water-closets. In the case of Nottingham, where middens, pails, and water-closets are in use in different parts of the town, Dr. Boobbyer has shown that the greatest prevalence of enteric fever is to be found in the houses with middens, and the least in the water-closeted houses, those with pails occupying an intermediate position.

However suitable the earth-closet system may be for country houses and villages in this country, and for villages and stations in India, and in cold countries, where the water supply is small and liable to interruptions, and where earth of suitable quality is easily procured and dried, and the compost can be distributed over gardens and fields in the immediate vicinity, it is quite inapplicable to towns of any size, on account of the enormous quantities of earth that would have to be dried and brought into the town, the difficulties of storing the earth on the premises of houses and keeping it dry, and the still larger quantity of nearly worthless manure to be removed out of the town and finally disposed of.

THE WATER-CARRIAGE SYSTEM.

In this system the solid excreta together with all liquid refuse are conveyed away—borne along by flowing water—in drains and sewers from the neighbourhood of houses and towns. In

many towns, before any general introduction of water-closets, sewers existed for conveying away house waste waters, stable drainage, surface and storm waters, and in some cases waste liquors from manufactories. These sewers, which were made of brick, oval or circular in section, acted also as land drains; for not being constructed of impermeable materials, they admitted subsoil water and had considerable effect in drying the soil.

It became at one time also the practice to drain off the liquid contents of privies and middens, or to carry overflow pipes from cesspools into these sewers, which in consequence speedily became choked with sediment. This sediment rapidly putrefied, and the offensive gases given off created an abominable nuisance. It then became necessary for the sewers to be regularly cleansed, and the deposit had to be removed at great expense by hand labour. The drainage of privies and middens entered the sewers in a most foul and offensive condition, owing to the putrid state of the contents of these receptacles. Another result was that the streams and rivers into which this sewage was permitted to pass became highly polluted. In many towns these brick sewers still exist, and perform the double function of removing sewage and rain-water, and draining the subsoil; whilst in others they are only permitted to perform their original function of carrying off rain and surface water and of draining the subsoil, impermeable sewers being laid to remove the sewage of the town on what is known as the *separate system*.

House Drainage Arrangements.

Water-closets.—A water-closet may be defined as an apparatus for the reception of excrement, which is connected with a sewer by a pipe, and in which water must be used to carry away the excrement deposited in it. It is therefore seen at once to differ in all essentials from a privy, which ought not to be connected in any way with a sewer, and in which water cannot properly be used. Water-closets may be classified under two heads: (*a*) those in which there is no movable apparatus for retaining water in the basin; (*b*) those in which there is such a movable apparatus. Under the first head are included the various types of *hopper closets* ; under the second head, *valve closets*.

The *hopper closet* consists of an inverted stoneware cone, connected below with a ∽ or ∫-shaped pipe, which retains sufficient water to prevent the free passage of air, and is known

as a *trap*. The old form of hopper closet, called the *long hopper*, from the length (about 18 inches) of the cone (fig. 14), is liable to fouling of the basin, and is difficult to flush, especially where the water is admitted by a side inlet, which has the effect of causing the water to whirl round and round, whereby the trap is not flushed out and excreta are left behind. A *short hopper* or

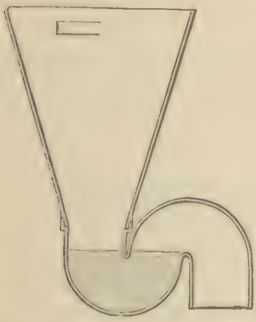

FIG. 14.—LONG HOPPER WATER-CLOSET WITH SIDE-INLET FOR FLUSHING.

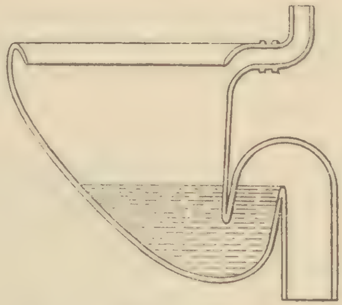

FIG. 15.—WASH-DOWN WATER-CLOSET.

wash-down (fig. 15) is constructed with a shorter (8 to 9 inches) cone of china or stoneware; the back of the cone should be made nearly vertical, so that the excrement drops into the water of the trap, and not upon the sides of the basin. The short hopper, especially when constructed with a "flushing rim," by which the sides of the basin are well washed, is found, under proper management, to be easily kept clean. It is a form of closet which is now largely used, for it is simple in construction, inexpensive, has no confined air space where foul air could accumulate, and conveys slop waters away at once, no overflow pipe being necessary.

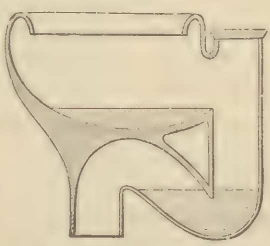

FIG. 16.—WASH-OUT WATER-CLOSET.

For the outdoor water-closets of the houses of the working classes the short hopper closet, made in stout glazed stoneware or fireclay, is far the best. The floor of the closet should not be of wood, but of cement-concrete sloped towards the door of the closet. The siphon trap under the closet basin should be fixed upon the cement floor by embedding it in cement so as to form

a pedestal, thus rendering it and the basin very strong and perfectly secure. There should be no vertical wooden casing, and the seat should be hinged, so that every corner around the space beneath the seat can be got at for cleansing. The trap of the closet should be joined at the back of the basin to a 4-inch stoneware drain pipe by a cemented joint. A closet fixed after this manner will stand a great deal of rough usage without getting broken or out of order.

Nearly all closets of the wash-down type are now made in pedestal form, that is to say, with a hinged, lifting seat, and without wooden casing or riser. The closet is then well adapted for use as a urinal and for the discharge of chamber slops. The space under the closet should be cemented or tiled, or lined with lead finished with a beaded border. In the bracket form of closets, the basin and trap are supported by galvanized cantilever brackets let into the wall, and do not rest on the floor, consequently all the space beneath the closet apparatus can be readily cleansed. Bracket closets are much used in hospitals.

The *wash-out closet* (fig. 16) is constructed of stoneware or china, with the basin so shaped that a small quantity of water remains in it to receive the excreta, which are flushed out over the edge of the basin into a siphon trap below. This form of closet is difficult to flush with only 2 gallons of water, for the rush of the water from the flushing cistern is broken by the force necessary to clear out the contents of the basin; and then the water falls into the trap, but often without sufficient impetus to propel the excreta through it. The basin, too, is very apt to become soiled by solid matters near the outlet. The basin—as in the case of every closet basin—should be provided with a flushing rim. These disadvantages have led to the disuse of wash-out closets.

Various "*siphonic*" closets are now made by English manufacturers, in which the contents of the basin are not only forced out by the water-flush, but are also sucked out by means of a temporarily induced siphonage in the trap. Not all of these closets are reliable, as in some cases it has been found that foul water returns to the basin after flushing; also in some forms of this closet, to prevent the siphon becoming "air bound," air-escape pipes have to be inserted—an undesirable complication of what should be a simple apparatus.

Water-waste preventing cisterns should be used with each of these three forms of closet, both for economy of water and to

break the connection between the house cistern, used for drinking water, and the water-closet basin. Where there is no house cistern, the water being supplied by constant service, the water-waste preventer is especially necessary. Outbreaks of enteric fever have been attributed to the ascent of foul air and liquid filth from water-closet basins up the supply pipes into the water mains, with which they were directly connected. One of the simplest forms of water-waste preventer merely has a spindle valve in the cistern on the supply pipe of the closet, which can be raised by pulling a chain attached to a lever, when the

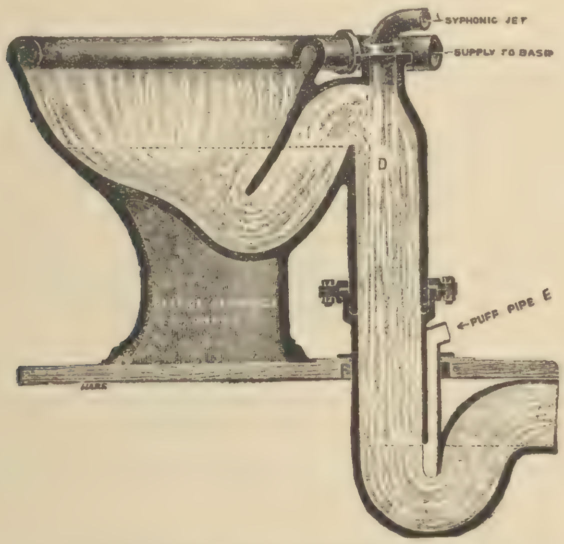

FIG. 17.—CENTURY SIPHONIC CLOSET.

water—2 or 2½ gallons—is discharged. When the lever is depressed by the chain, the ball valve is raised, and no more water can enter the waste preventer as long as the chain is held. The chain must be held until the waste preventer is empty.

The best form of water-waste preventer is that with a siphon action. A very short pull of the chain will put the siphon in action, when the whole contents of the cistern are discharged through the flush pipe of 1¼ to 1½ inches in diameter. No more water can then escape until the cistern is refilled and the chain again pulled. There are numerous forms of siphon water-waste preventer. The especial advantage of the siphon action is that

the cistern is emptied by a very short pull of the chain—an important factor in the proper flushing of closets used by careless persons.

These cisterns should be fixed at a height of not less than 4 feet above the closet basin. If this " head " is not obtainable, a good flush can be secured, as in the " combination " closets, by using a cistern, fixed just above the seat level, with a comparatively large outlet pipe, which is only narrowed just before it joins the basin.

The joint between the china or stoneware trap and lead soil pipe is difficult to make perfectly secure with red lead as a jointing material. Therefore it is better for these closets, where they must be connected to a lead soil pipe, to have lead traps, as a wiped joint can be easily made between the closet trap and the soil pipe. The disadvantage of the lead trap is that it cannot be enamelled internally, and enamel paints soon wear off, giving a dirty appearance to the bottom of the closet. In most cases a good joint is made by wiping a brass collar on to the lead soil pipe, when the joint between the china trap and brass collar is made with Portland cement, a little asbestos packing being employed to prevent the cement finding its way into the interior of the pipe.

Under the head of closets with a movable apparatus for retaining water in the basin, we have the pan, the valve, and the plug closets, but only the valve closet need be described, as pan and plug closets are no longer manufactured, and are only very occasionally now to be found.

The *valve closet* (fig. 18), which is now largely in use, consists of a hemispherical basin of china or stoneware, with a circular outlet at its lowest part, 3 inches in diameter. This outlet is closed by a circular water-tight clack valve, hinged at one side, where it is connected with the handle of the closet. On raising the handle, the free edge of the valve is depressed into a metal valve box, just large enough to allow the valve to assume a perpendicular position. The valve box is connected at its lower part with a trap—preferably a siphon trap, or an anti-D trap formed of 4-inch lead pipe—and the outlet of this trap is connected with the soil pipe. The valve closet should be flushed from a small cistern holding 6 or 8 gallons of water, and not from a waste-water preventer, as it is necessary to provide a considerable " after-flush "—that is to say, to allow a supply of

water to enter the basin after the handle is released and the valve closed. This is effected by means of a "bellows regulator" actuating a valve in the supply pipe from the cistern to the closet basin.

As the outlet to the closet basin is guarded by a water-tight valve, the basin may overflow from too much after-flush, or from the throwing in of slops. It is necessary, therefore, to provide an overflow pipe to the basin; this is usually carried from near the top of the basin into the valve box below, after forming a U bend, which, by holding water, prevents the ascent of foul air from the valve box.

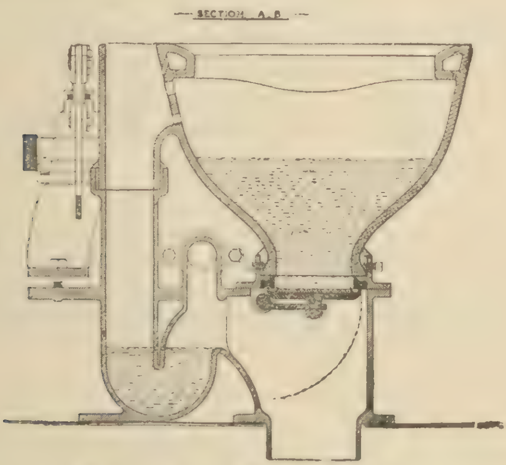

FIG. 18.—ERA VALVE CLOSET.

There is very little risk of the deposition of filth in any part of the apparatus, as the large volume of water which the basin can contain effectually flushes the small valve box and trap beneath. Occasionally the valve box is enamelled inside to prevent corrosion.

Wherever a valve closet is used as a urinal or for the reception of chamber slops, a white ware slop-top should be fitted, and the seat should be hinged for lifting. Valve closets are also now made in pedestal form, so as to obviate the wooden casing and riser. An advantage possessed by valve closets over the wash-down closets is that the flushing is comparatively noiseless; and this fact accounts for their popularity in the best class of residential property.

In the *anti*-**D** *trap* the calibre of the pipe is diminished in the bent portion which holds the trapping water, and the bend of the pipe beyond the trap instead of being circular is squared. These properties cause some resistance to the passage of water through the trap, and tend to prevent both *siphonage by suction* —*i.e.*, the drawing of the water in the trap by the passage of water down the soil pipe from a higher level—and *siphonage by momentum*, which may occur in plain siphon traps by the water discharged from the water-closet sweeping through the trap, insufficient remaining behind to form the water-seal. The depth of the water-seal in water-closet traps should not be less than 1 inch, and not greater than 1¾ inches. If the depth of the water-seal is too small, there is a liability for the trap to be unsealed; if the seal is too great, the trap and the closet above it are not self-cleansing with an ordinary flush of water. These remarks apply more especially to "wash-down" closets (short hoppers) with waste-water preventers.

The Water-seal of Traps.—The water-seal of a trap is the vertical distance between the level at which water stands when the trap is fixed in position, and the lowest point of the bend of the upper surface of the trap. Thus in figs. 19 and 20, which are diagrammatic sections of an **S**-trap and a **P**-trap, in each case the water-seal is the same, namely, the vertical distance AB in the case of the **S**-trap,

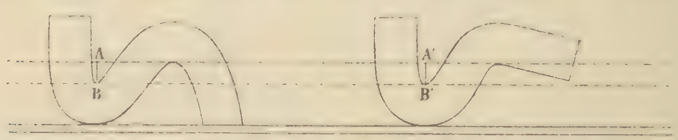

FIG. 19.—**S**-TRAP, WITH WATER-SEAL. FIG. 20.—**P**-TRAP, WITH WATER-SEAL.

and the vertical distance A′B′ in the case of the **P**-trap. The water-seal is, in fact, the depth of water that opposes the passage of air or gases from one side of the trap to the other, from outlet to inlet or from inlet to outlet. In the figures, the upper dotted line represents the water-level in each trap, and the lower dotted line is parallel with the upper dotted line, and is tangential to the apices of the bends.

On the floor beneath the basin of a valve or plug closet is usually placed a lead *safe-tray*, to catch any overflow. This tray should be provided with a waste pipe, which must be carried through the wall into the outer air, its end being covered by a brass flapper to prevent cold currents of air passing into the house.

Water-closets should be placed against the outside wall of a

building, in which is a window with an area of at least 2 square feet, made to open, and reaching to the ceiling. Where possible they should be separated from the house by a well-ventilated lobby, for it is important that air from the closet should find an easy exit to the outer air, and not pass into the house, as so often happens when water-closets are placed in dark, unventilated corners. The water-closet must not open directly into any living-room, factory, workshop, or compartment in which food is stored. The division wall between the water-closet and a dwelling-room, or a factory, or workshop, or food store, should always be of brick, and not a porous lath and plaster structure.

The *trough closet* is used in large establishments, as hospitals, schools, workhouses, and asylums. One apparatus serves for

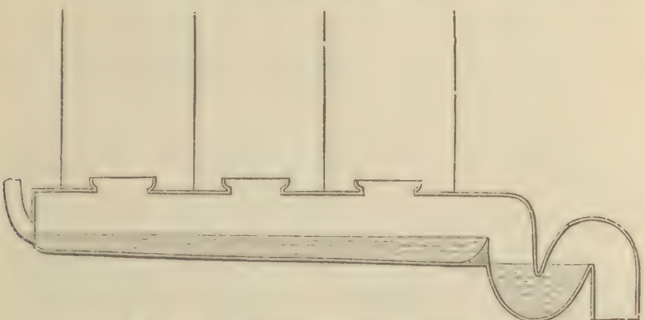

FIG. 21.—TROUGH WATER-CLOSET.

the use of several people at the same time, and the flushing can be rendered automatic. The old form of closet (fig. 21) consists of an open trough, usually of stoneware, with rounded bottom, of varying length according to the number of compartments desired. The trough has a slight incline towards the drain; and by means of a weir at its lower end it is able to retain sufficient water to cover the bottom for its whole length. It terminates in a siphon trap protected by a grid, to keep back articles improperly thrown in, before joining the drain. Each seat over the trough should be in a separate compartment. The closet may be flushed by means of a Field's annular siphon flush tank (*see* fig. 13) of capacity proportional to the length of the trough to be flushed.

The more modern and approved type of trough w.c. or latrine is a great improvement upon the old form. In this (fig. 22) the trough is retained, but each closet is cut off from its neighbours

by a separate basin, the outlet from which dips into the water in the trough. The trough, moreover, is kept filled with water, which also rises up for a few inches into each w.c. basin; this is effected by doing away with the weir and substituting a high siphon trap at the outlet to the trough. Each separate basin is flushed through its flushing rim every time the automatic

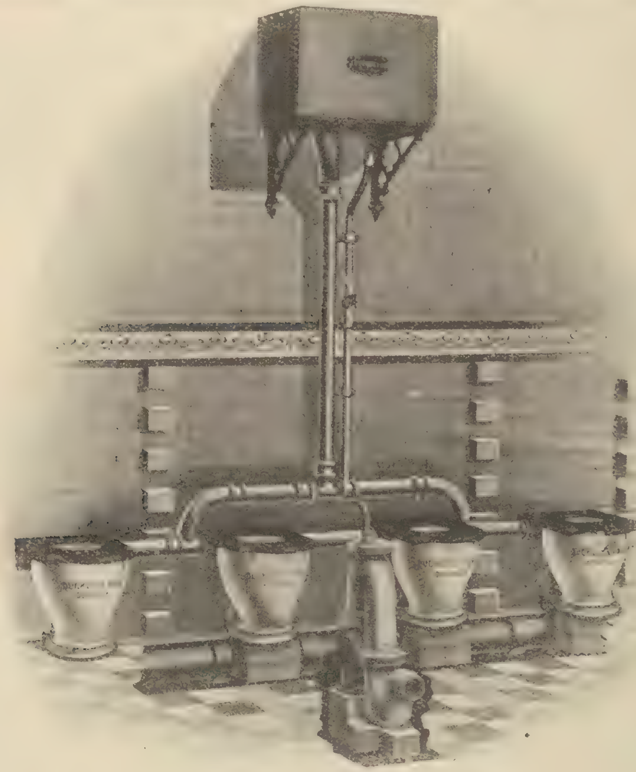

FIG. 22.—NEW FORM OF TROUGH CLOSET OR LATRINE WITH ISOLATED PANS.

flush tank discharges, this discharge causing the emptying of the basins and trough by siphonic action. On the whole, trough closets have not been found to be very satisfactory in practice, and in schools and institutions they are now being replaced by separate pedestal wash-down closets.

Waste-water closets, in which the excreta are carried away by means of the house waste-waters, and in which flushing cisterns

with separate water supply are not used, have been installed in many working-class houses in Midland towns, but the closets have not been found satisfactory in practice, and the system is generally condemned.

Urinals should be made of non-corrosive materials, such as fireclay, slate, and stoneware; all metal apparatus is liable to corrosion, and should not be used. The best form of urinal is the stall, with rounded back, sides, and channel floor, all in one piece of ware, the channel discharging into a siphon trap connected with a soil pipe or drain, and not into a gulley. The best kind of flush is that from siphon-action flush tanks which discharge automatically at regular intervals. Unless urinals are regularly and freely flushed with water, there will be a deposit of urates in the attached lead waste pipe, soil pipe, or drain, which by continual accretion and hardening eventually leads to obstruction. Where urinals are not supplied with water, there is usually a nuisance from smell, but this can be largely obviated by brushing the backs and sides daily with paraffin.

Slop sinks should be used only where it is objectionable to discharge slops from bedrooms through the water-closets. They are usually short hopper china basins with a siphon trap below, protected by a grid to keep back the larger foreign bodies which might obstruct the pipes. The trap should be connected with the soil pipe like a water-closet. They should be provided with a flushing rim, and flushed from a water-waste preventer.

Soil pipes are used to receive the contents of water-closets, urinals, and slop sinks, which are above the basement or ground level. They should be circular in section, and $3\frac{1}{2}$ or 4 inches in diameter, these being the most convenient sizes for ordinary use. They should be of drawn, milled, or rolled lead, 8 pounds to the square foot, or 9 pounds to the square foot for very high buildings, without any longitudinal seam, and should be fixed outside the house, with wiped (soldered) joints between the different lengths of pipe, each pipe being 10 feet in length. Lead T-pieces are used to receive the branches from the water-closets.

The London County Council bye-laws require $3\frac{1}{2}$-inch lead soil pipes to weigh not less than 65 lb. per 10 feet length, and 4-inch pipes not less than 74 lb. per 10 feet length. The thickness of metal of $3\frac{1}{2}$-inch and 4-inch iron soil pipes must not be less than $\frac{3}{16}$ inch; and the weight of 4-inch iron pipes per 6 feet length (including socket and headed spigot or flanges, the socket not to be less than $\frac{1}{4}$ inch thick) must be not less than 54 lb.

Soil pipes outside the house are often made of light cast iron or galvanized iron. They are inferior to lead pipes, as the internal surface of iron pipes is much rougher than that of lead, and the joints as usually made with red lead putty are insecure. Heavy cast-iron socketed soil pipes are in some cases insisted on by local drainage bye-laws, especial precautions being laid down for the construction of the joints between the different lengths. To prevent oxidation and the formation of rust, iron soil pipes should be coated inside and outside with the magnetic oxide of iron (Barff's process), with hot coal-tar pitch, or with Angus Smith's solution. All cast-iron pipes must be free from holes or other defects, and properly tested, and of a uniform thickness of not less than $\frac{3}{16}$ inch. The joints between the different lengths must be caulked[1] with lead; and the joints between the iron pipe and the lead T-pieces from the closets should be made with a brass ferrule, caulked in with lead, the lead pipe being attached to the ferrule by a wiped joint. Heavy iron soil pipes are heavier than lead pipes in the proportion of about 9 to 7.4.

Joints of Pipes.—In making a wiped soldered joint on lead pipes, the upper end of the lower pipe is opened out about $\frac{1}{4}$ inch. The lower end of the upper or male pipe is next rasped so as to make it fit into the opened-out end of the female pipe. The ends of the pipes which are to be covered with solder are next shaved with a shave hook, so as to take the dulness off the lead and allow the solder to readily tin upon them.

Above and below the soldered line (fig. 23) the pipes are then soiled round with plumber's soil (a mixture of lampblack and size) to prevent the solder adhering. It is well also to soil the insides of the pipes to prevent the solder adhering here and causing projections. The male end is next fixed into the female end, and a collar placed round the bottom of the joint to catch the solder as it falls off. The heated solder (a mixture of two parts of soft lead to one of tin) is then poured over the shaped ends of the pipes, and gradually worked into the right shape. A hot moleskin cloth is now taken and wiped round the joint, so as to leave it of the shape shown in fig. 23. As the pipes become heated by the solder splashed over them, the solder penetrates between the ends of the pipes and readily adheres to all the shaved bright surfaces exposed, leaving when cool a homogeneous mass of metal. Fig. 24 shows a joint made with a copper bit or blow-

[1] A caulked lead joint is a joint made by firmly packing lead strips into the socket of the iron pipe by means of a caulking tool (which is in the form of a blunt chisel) and a hammer. The lead is known in the trade as "ribbon" lead. It should be quite free from oxide, and therefore must only be used when fresh. This process has now largely superseded the older method of caulking with oakum and filling in with molten lead.

pipe. The ends of the pipe are heated either with a copper bit or blowpipe, and, when hot, the solder is poured around the point of junction and penetrates between the cut ends. A very good joint is thus obtained with little trouble, but inferior in strength to the wiped joint with its strengthening band of solder.

A new method of jointing pipes has lately been introduced, which is intended to supersede the old-fashioned soldering methods. For jointing lead pipes a cutting tool is used, the ends of the pipe being shaped into a coned joint, and the surfaces left in perfect apposition. A substance called "Amalgaline" is then inserted between the cut ends, and the exterior of the joint is heated with a flame. Amalgaline consists of a metallic ribbon, 0·05 millimetre thick, coated with a composition to prevent oxidation. On the application of heat, the ribbon melts at a lower temperature than the metals to be acted upon, and causes an amalgamation of the metals at a considerably lower temperature than their normal melting-point.

FIG. 23.

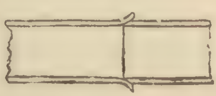

FIG. 24.

The joints between iron pipes can only be caulked with lead when the pipes are of sufficient substance and strength to stand it. The joints of the light iron pipes commonly used are made with spun yarn and red lead, or occasionally with Portland cement.

If lead soil pipes are used where much hot water is discharged through water-closets or slop sinks connected with them, owing to the expansion of the metal of the rigid pipe, twisting and contortion take place (the pipes are said to "buckle"), and such pipes readily wear out. Under such circumstances, either iron soil pipes should be used, or the lead pipes, if outside the house and not near windows, should have slip joints or rubber expansion joints.[1] For this reason, also, south and west aspects, involving much exposure to the sun, should be avoided for lead soil pipes.

With the precautions noted above, and under skilled work-

[1] A slip joint is made by slipping the end of one pipe into the slightly expanded end of another pipe, so that the one fits more or less firmly into the other, but allowing a certain amount of play for expansion.

manship, cast-iron soil pipes may be used outside a house. Stoneware, zinc, or wrought iron should never be used for soil pipes; for stoneware is too heavy, and zinc is thin and liable, like iron, to erosions. The proper fixing of a lead soil pipe by means of cast lead ears or tacks to the walls of the house at intervals of 3-4 feet, to insure its being perfectly rigid, is a point of importance; if not securely fixed, there will be strain on some or all of the joints, with the result of their becoming insecure. Outside soil pipes should be connected with the house drain by a plain stoneware bend below the ground level, a thimble or ferrule of rough brass casting being wiped on to the lead pipe and a Portland cement joint being made between the brass and stoneware. An iron soil pipe should be connected with the stoneware drain by receiving the spigot end of the iron soil pipe into the socket end of the stoneware drain, and making the joint with Portland cement. When a branch lead soil pipe has to be connected to a heavy iron main soil pipe a brass ferrule or thimble is soldered to the lower end of the lead pipe, and the ferrule is then jointed with the socket of the iron pipe by means of hemp and molten lead, or the "ribbon" lead previously alluded to. All soil pipes, whether inside or outside the house, should be carried up full bore above the entrance of the branch from the highest water-closet to the top of the house (fig. 25) above the ridge of the roof, clear of all windows and chimneys, their ends being left open or covered merely with a wire-gauze dome to prevent birds from building in them. Cowls should not be placed on the tops of soil-pipe ventilators. They are useless as aids to extraction of air; and they very frequently lead to obstruction of the outlet, besides being perishable.

Where one soil pipe receives the discharges of several water-closets on different floors, the passage of the contents of one of the upper closets down the soil pipe may cause the water in the trap of one of the lower closets to be drawn off, owing to the suctional force of the downward current of air caused by the descent of the liquid in the soil pipe. To prevent this siphonage by suction taking place, a 2-inch or $2\frac{1}{2}$-inch lead ventilating pipe should be carried up from every branch soil pipe, a few inches beyond the trap (on its soil pipe side), and these anti-siphonage pipes should join with one another on their way up outside the house, the common pipe being carried up separately or connected with the ventilator to the soil pipe (fig. 25). By this means the

water-closet traps will not be disturbed by the passage of liquid down the soil pipe, for air will be sucked down these anti-siphonage pipes to restore the disturbed equilibrium. Siphonage is most likely to occur in $3\frac{1}{2}$-inch lead soil pipes where the branch pipes from the water-closet traps to the soil pipe are long and curved. If they are short and straight, there is less likelihood of siphonage occurring. The long arms or branches from water-closets thus ventilated are relieved of foul air which otherwise accumulates in them, and eventually leads to erosion and perforation of the metal of which the pipes are made. A trap at the foot of the soil pipe immensely intensifies siphonage by suction.

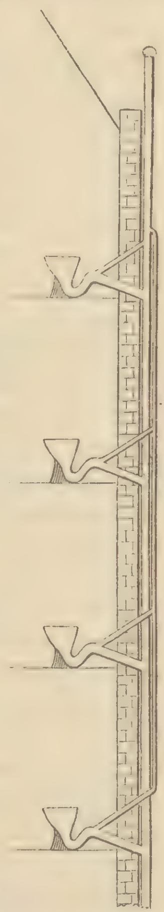

FIG. 25.—SOIL PIPE AND VENTILATOR, WITH ANTI-SIPHONAGE PIPES FROM THE WATER-CLOSET BRANCHES.

Rain-water pipes from the roof should not be used as soil pipes and ventilators, for during heavy rain, when it may be most necessary to give a safe exit for displaced drain air, they will be useless as ventilators, and foul air from unventilated drains may be forced through water-closet traps into the houses. Moreover, the joints of rain-water pipes are frequently found to be defective; and if the pipe passed near to windows there would be a risk of drain gases finding an entrance into the house.

House drains are usually constructed of circular glazed stoneware socketed pipes, 2 feet in length, with cemented joints (Portland cement). The pipes are also connected by Stanford's patent joints or Doulton's modification (which makes the pipes adjustable in any position), in which the spigot and socket ends of each pipe are provided with a mould of smooth plastic material, causing them to fit accurately into each other when in position, a very perfect joint being formed by greasing the prepared ends with a little rosin and melted tallow. These patent joints, however, are inferior to cement, as they are liable to erosion and decay, and are usually found not to be water-tight some years after laying.

Stoneware pipes are less porous and more durable than earthen-

ware pipes; the former may be distinguished from the latter by their colour (generally pale buff), the ringing note which they give out on being struck with a hammer, and their comparatively slight increase in weight after twenty-four hours' immersion in water.

Portland cement is a mixture of chalk and clay burnt at a high temperature and subsequently ground very fine. It is stronger and capable of bearing greater tensile strains than other cements (Roman and Medina), but does not set so rapidly When cemented joints are made, neat Portland cement only should be used, and care must be taken to remove any cement projecting from the interior of the joint into the drain, which when hardened would form an obstruction to the flow of sewage through the drain. Portland cement should be spread out and exposed to the air for some time before it is used, otherwise the joints, when made, are apt to "blow," and the collars become fractured. Socketed cast-iron pipes coated inside and outside with some preservative material such as the magnetic oxide of iron (Barff process) or Angus Smith's solution, to prevent oxidation, are used when the drain is required to be of extra strength to withstand constant vibration, as when laid under roads or paths on which there is heavy traffic, and also in soft, swampy ground. The joints of an iron drain must be caulked with molten lead and gasket or hemp (old method), or with "ribbon" lead (new method). Iron pipes have advantages over stoneware, as they are made in 9-feet and 12-feet lengths, and consequently fewer joints are required; the pipes are stronger, and the caulked lead joints more durable, and they are capable of resisting strains that would fracture stoneware pipes; on the other hand, the interiors of even the best-protected iron drains are liable to rusting and erosion in course of time, a defect which the less costly stoneware drains are free from.

When it is necessary to connect a lead to a heavy iron pipe, a strong brass ferrule or thimble should be joined to the lead pipe by means of a wiped soldered joint; the brass ferrule is then received into the socket of the iron pipe and the joint made with hemp and molten lead, or "ribbon" lead.

For small and medium-sized houses a drain 4 inches in diameter is the proper size; for large houses a 6-inch drain may be used, and for large institutions or establishments consisting of several buildings a 9-inch drain may rarely be required. The smaller

the drain, the better the flushing and removal of deposit; but the drain must in all cases be large enough to guard against blockage and to carry off at all times all the rainfall over the area drained, as well as the maximum flow of sewage proper of the house. A volume of water sufficient to make a 4-inch pipe run full causes a 6-inch pipe to run less than half-full, and a 9-inch pipe only about a quarter-full, when all three are laid at the same inclination, since the sectional areas of the three pipes are in the ratio of about 1, 2, and 5.

Stoneware drains are made in 3-inch, 4-inch, 6-inch, 9-inch, 12-inch, 15-inch, and 18-inch sizes. Iron drains are made in these sizes, and in addition 5 inches in diameter—a size which is very frequently employed.

The London County Council bye-laws require stoneware drains (4-inch and 6-inch) to be not less than $\frac{5}{8}$ inch in thickness; the depth of the socket to be $1\frac{3}{4}$ inches for 4-inch, and 2 inches for 6-inch pipes; and the annular space for the cement to be not less than $\frac{5}{16}$ inch for both 4-inch and 6-inch drains. For iron drains (4-inch, 5-inch, and 6-inch) the thickness of metal must not be less than $\frac{3}{8}$ inch; and the weight per 9 feet length (including socket and beaded spigot or flanges, the socket not to be less than $\frac{3}{8}$ inch thick) must not be less than 160 lb. for 4-inch drains, 190 lb. for 5-inch drains, and 230 lb. for 6-inch drains.

The pipes must be laid (with the socket end pointing upwards towards the head or commencement of the drain) on a perfectly smooth incline of hard ground, or where passing under the basement of a house, on a bed of 6 inches of cement concrete, the drain being embedded to the extent of half its diameter. In London it is the practice in addition to cover stoneware drains with 6 inches of cement concrete all round, the concrete projecting on each side of the drain to an extent equal to the external diameter of the drain. Concrete should be made of clean sharp sand, 2 parts; clean ballast (gravel, or hard brick broken small), 6 parts; Portland cement, 1 part. Each pipe should rest upon the concrete for its whole length, so that the drain may be truly laid, the lumen of each pipe being concentric with the next. The concrete should be hollowed out where the collar of the pipe rests, and the cement must be introduced all round the joint, below as well as above; and the joint should be finished with the trowel. It is sometimes the practice to introduce a strand of spun yarn into the interior of the joint to prevent the cement passing into the drain, and to insure the

thickness of cement being the same all round. It is often the custom now to lay the drain on bricks at the bottom of the trench, and when the joints have been made with cement, to fill in with concrete beneath the pipes. If this is done, a brick should be used to support each end of every pipe, so that the drain may be truly laid. Iron drains should be laid on 6 inches of concrete, where passing under a building, as above described for stoneware drains, but need not be embedded in concrete.

The gradient of a 4-inch drain should, if possible, be not less than 1 in 40, of a 6-inch drain 1 in 60, and of a 9-inch drain 1 in 90; this will give in each case a velocity of flow of between 3 and 4 feet per second. The drain should not, wherever it can be avoided, be carried under the basement of a house. Where, however, this is unavoidable, the special precautions noticed above must be taken, and at the point where the drain leaves the premises the wall should be supported by a relieving arch to prevent settlement and fracture of the pipes.

Drains should be laid as far as possible in straight lines. If a bend is necessary, it should be effected by means of a special pipe curved to the proper degree, and the radius of any curve should not be less than ten times the cross-sectional diameter of the drain or sewer. The bends most commonly used are known as $\frac{1}{4}$, $\frac{1}{8}$, and $\frac{1}{16}$ bends, implying that if 4, 8, or 16 respectively of these pipes are placed together they will form a complete circle. A branch drain should be made to join the main drain by means of a V-junction pipe, so that the branch current may be flowing nearly in the direction of the main current, thus causing no obstruction at the point of union. In large houses it is very often impossible to carry the drain in a straight line for its whole length. It is advisable in these cases, at every change of direction, to provide means of inspection by manhole chambers, the drain being continued through the floor of the chamber by a suitably curved channel pipe, *i.e.*, a pipe divided longitudinally in half. Into these inspection-chambers the branch drains also should be made to discharge by means of short curved channel pipes emptying over the main channel. Winser's curved channel pipes, from which about a quarter section only of the circumference has been removed, should be used when connected with a high soil pipe, so as to avoid splashing of solid fæcal matters over the floor of the chamber; and where the drains are joined in a manhole, the invert or bottom of the smaller drain should be

higher than that of the main by so much as the difference between the diameters of the two, so as to prevent the liquid flowing in the large or main drain from backing up into the smaller. By this system of manhole or inspection-chambers, the drain—which runs in a straight line from manhole to manhole—can be inspected, and cleared by rods of deposit or obstructions, without breaking into it. Where it is necessary to connect a small pipe with a larger pipe, the junction should always be effected by means of a taper or diminishing pipe.

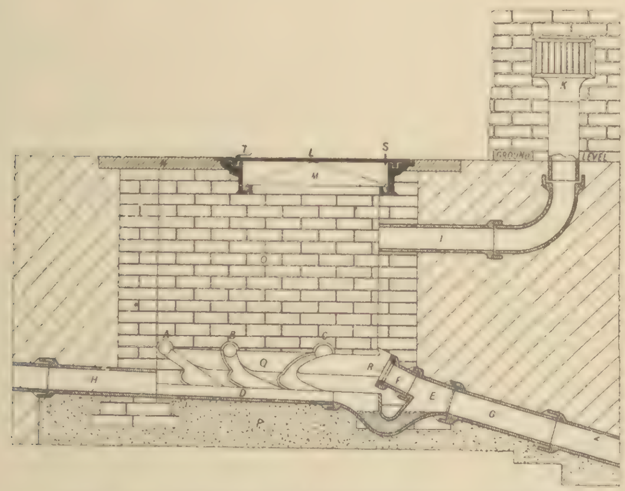

FIG. 26.—SECTION OF DISCONNECTING CHAMBER.

A, junction 45° (4″); *B*, junction 90° (4″); *C*, junction 30° (4″); *D*, main channel (4″); *E*, intercepting trap (4″ to 6″); *F*, clearing eye; *G*, drain to sewer (6″); *H*, drain (4″); *I*, fresh air inlet; *K*, galvanized terminal; *L*, air-tight cover; *M*, condensing dome; *N*, York stone; *O*, glazed bricks, or preferably brickwork rendered in Portland cement; *P*, concrete; *Q*, cement ramps; *R*, cap to clearing eye; *S*, water joint automatically sealed by condensation; *T*, ordinary joint, tallow or soft soap.

The *disconnection of the house drain* from the public sewer is generally provided for, although it is not now generally held that sewer air is more specially harmful than drain air. Siphon disconnecting traps, however, prevent the passage of sewer rats up the house drains; and unless such traps are fixed, it would be impossible to provide for the ventilation of house drains by fresh air inlets as now practised. Disconnection is effected by interposing a siphon trap between the house drain and the sewer, and on the house side of the trap a means of inlet for fresh air

into the house drain is provided. The point usually chosen for disconnection is immediately before the house drain leaves the premises in its course to the street sewer. If the house drain is provided with a ventilating pipe at the further end, air, admitted on the house side of the disconnecting trap, will generally travel continuously from the lower opening to the higher, and a circulation will thus be established in the drain and soil pipe, preventing any accumulation of foul air.

The simplest form of disconnecting apparatus consists of a siphon trap with fresh air inlet formed of stoneware pipes on the house side of the water seal. There are several varieties of this sort of trap sold, under the names of "sewer air intercepter," "sewer air trap," etc. The points to be observed in choosing a trap of this description are: (1) Where the drain is a 6-inch or a 9-inch pipe, the siphon should be a size smaller than the drain; (2) there should be a fall of 2 inches or more from the level of the discharging end of the house drain to the surface of the trapping water; (3) the siphon should provide an adequate seal of 2 or 3 inches of water; (4) the inlet to the siphon should be nearly vertical, whilst the outlet rises at an angle of not more than 45°. These qualities, except (3), are necessary to insure sufficient flushing of the trap; and, to further attain this end, the drain should be laid with a slightly greater fall before its junction with the trap. The fresh air inlet to the siphon is continued up by a vertical pipe to a little above the surface of the ground, and there covered by an open iron grating, which may be guarded by a mica flap valve to prevent any escape of foul air.

There is no doubt that the odour of drain and sewer gases plays an important part in determining injurious effects upon health, for rapid and profound constitutional disturbances are often induced by foul odours, the effect of which often lasts for some time, and may render the individual specially prone to certain infections. Doubtless the short length of house drain, with its greater fall, generally leads to that pipe keeping cleaner than the long common pipe or sewer into which it discharges; and since the offensive sewage gases are produced in proportion to the time during which the sewage remains in the pipe, the atmosphere of sewers is, generally speaking, fouler than that of drains. Another circumstance favouring the retention of the disconnecting trap between the house drain and the sewer is that the faulty condition of stoneware drains, so frequently discovered, is re-

sponsible for the fact that a considerable number of house drains are always under repair, and for this purpose they may be open for several days; the dangers to the occupants would be increased if during these occasions the drains were ventilating the sewer. It is claimed that without using intercepting traps the gases from the sewer would be distributed by escaping through the drain and soil pipe of each house; but no such equable distribution of escaping gases would occur in a district of varying levels, with houses which varied a great deal in their size, height, and proximity to the sewer, and in which the sewers were not uniformly sound and of equal gradient. In a comparatively flat district with a recent and well-laid system of sewerage, or in newly-developed districts in which iron drainage is provided for the dwellings, there would be little advantage derived from intercepting the house drains; but if the intercepters are properly fixed, of a good type, and always cleared before the drainage is covered up, they very rarely give rise to any trouble.

In larger houses it is now usual to provide a *disconnecting manhole chamber* (fig. 26), instead of the simple trap above described. The chamber walls are built of brickwork rendered in cement, and the floor is made of concrete. Walls lined with glazed brick are not so good as rendered walls, as the joints in the brickwork are apt to become defective, and then the chamber is no longer water-tight. The drain is continued through the floor of the manhole in the form of a glazed channel pipe, from which the floor—made of cement—slopes up (ramps or benchings) at an angle of 30° to the brick walls of the manhole. The branch drains, in the form of suitably curved ($\frac{1}{2}$ or $\frac{3}{4}$) glazed channel pipes, are made to discharge over the main channel, which itself discharges into a trap. The siphon trap should be provided with a "raking" arm or clearing eye, one end of which opens into the manhole, the other end being connected with the drain beyond the trap. This arm is to permit of obstructions being removed from the drain between the siphon trap and the sewer; when not in use, the manhole end should be closed with a patent stopper or a tile or piece of slate set in cement. The manhole chamber may be closed above by an air-tight iron cover; and the fresh air should then be admitted into the chamber by a 6-inch pipe, the manhole end of the pipe being opposite the entrance of the drain, whilst the end open to the air is covered by an iron grating and provided with mica flaps,

which permit air to pass in but prevent the reflux of foul air. The double seal condensing cover (fig. 26) is frequently used where the manhole chamber must be built inside the walls of a house. Where the disconnecting chamber is some distance from the house and away from footpaths, fresh air may be admitted by perforations in the iron cover. The chief advantage of the manhole chamber is the readiness with which the drain can be inspected and cleansed.

Wherever possible, the plan of drainage should be so designed as to provide for all manhole inspection-chambers being situated in yards or open areas, and not actually within the walls of the house; for there is generally some danger of escape of drain air through covers which are not perfectly air-tight. It is important also that the interiors of manholes should be rendered in cement, so as to be water-tight, in case they become choked and the chamber fills with sewage. Drain-clearing rods are usually 100 feet in length, and so where there are several manholes in a drainage system, they should not be more than this distance apart.

For house drains with insufficient gradient, in which deposit is liable to occur, it is advisable to provide an automatic flush tank to discharge into a gulley at the head of the drain; by this means the dangers arising from insufficient fall may be to a great extent obviated. Automatic flush tanks should be fed with clean water and not with bath or other dirty waste waters. Flush tanks fed with dirty waste waters invariably become a nuisance.

The frequency of discharge of the tank can be regulated by adjusting the tap through which the water enters; the merest dribble is usually quite sufficient. These tanks in practice should work without "dribbling" or "continuous action," which can be secured by fixing them on a perfectly level surface with the discharge pipe quite plumb. Flush tanks are now usually fitted with a "reversed" ball-valve. When the ball is depressed in the tank very little water passes through the valve; but when the tank is very nearly full the valve is fully opened, a rush of water enters the tank, and siphonage at once takes place. Dribbling and continuous action, which are sometimes due to smallness of flow into the tank, are thus avoided, whilst the time of filling the tank can still be regulated as desired.

All *waste pipes* from baths, lavatories, sinks, and safe-trays

under water-closets or baths must be disconnected from the drain or soil pipe by being made to discharge into the open air. The waste pipes from baths, lavatories, and sinks should be of a large diameter ($1\frac{1}{2}$ or 2 inches) to insure rapid emptying of the baths, sinks, etc., and as short as possible, for they tend to become coated internally with a deposit of dirt and soap, which decomposes and may be productive of nuisance. To prevent foul air from these pipes entering the house, a cast-lead siphon trap should be fixed under every bath, lavatory, and sink; and in the case of kitchen sinks this siphon trap should be provided at its lowest point with a screw cap, capable of removal, in order to clear the trap of sediment and grease. The waste pipes from the upper floors are often carried through the external walls to discharge into the open head of a rain-water pipe divided, if necessary, into lengths for this purpose; but this is not a very good plan if the open heads are anywhere near windows, for the iron pipes become in course of time much fouled from soap and dirt, and then are apt to smell offensively. In such cases the 2-inch lead waste pipe should be continued down to the gulley at the ground level, its upper end being carried up to the roof and left open; anti-siphonage pipes will usually be required in the case of bath and lavatory wash-hand basin waste pipes, to prevent siphonage of traps, especially where several waste pipes on different floors discharge into a main waste pipe. Every rain-water or waste pipe must be disconnected from the drain at its foot by opening over or under the iron grating over a stoneware siphon yard gulley. The basement waste pipes may discharge into yard gulleys by side inlets. When it is impossible to avoid having a long waste pipe, this must be ventilated by a pipe of its own diameter carried up outside the house to a convenient point. Whenever it is necessary to place waste or other pipes within partitions or recesses in walls, they should never be covered, except with woodwork, which should always be made readily removable.

The *surface water* from yards and areas should, where possible, be carried off by those siphon gulleys which receive the waste waters from the house, because these gulleys are always efficiently trapped in dry weather. Yard gulleys used for surface water only become untrapped in dry weather, owing to the evaporation of the water in them. These gulleys for waste and surface water are connected with branch drains which join the main drain

in the inspection or manhole chambers before referred to; they require to be cleansed periodically of sand and dirt, which collect at the bottom of the trap.

In large houses it is found that the sand and grease discharged through the kitchen or scullery sink are apt to lodge in the drain from the gradual solidification of the grease as the water cools, and so form an obstruction. It is usual in such cases to cause the waste pipe (2-inch pipe, trapped under the sink) to discharge into a *grease gulley* instead of into a yard gulley. This *grease gulley* is made of stoneware, and may with advantage be connected with an automatic siphon flush tank (fig. 27). The hot water from the sink is cooled on entering a large volume of cold water in the trap, the grease solidifies and rises to the top, whilst the sand sinks to the bottom of the trap. When the flush tank discharges, the grease is thoroughly broken up by the sudden inrush of the large volume of water, and is then carried along through the drain without any opportunity being given to it to deposit on the sides or floors of the pipes. The grease gulley should be covered above by a grating, and sunk a little beneath the surface of the adjoining ground to confine all splashings to the trap.

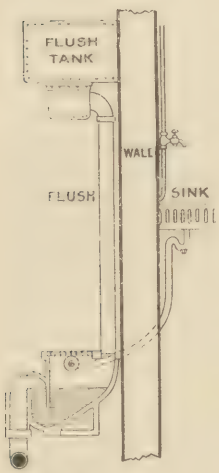

Fig. 27.

To carry off the water used for washing down laundries, sculleries, and dairies, the floors should slope to a channel leading to a yard gulley outside the house.

The house drainage arrangements described above have for their object: (1) The speediest possible removal from the house to the public sewer of excretal and other refuse by means of water; (2) the prevention of deposit of foul matter in any part of the drainage system, and of percolation into the soil of polluting liquids; (3) the establishment of a current of air through every part of the soil drains and pipes, in order to disperse any foul gases that may form, and allow them to escape with safety into the open air; (4) the prevention of any entry of gases from soil pipes, drains, and waste pipes, into the house; (5) the exclusion of the air of the common sewer from the house drain and the house.

THE TESTING OF DRAINS AND SOIL PIPES AND THEIR BRANCHES.

Tests are employed for new sanitary work, during the progress of the work, to ascertain that it is being properly constructed, and also for sanitary works that have been in existence for some time, to ascertain if the work is still sound. The principal tests are the water or hydraulic test, the smoke test, the pneumatic or air test, and the chemical test.

The Water Test.—This test is now almost invariably employed for new drainage work, and is applied after the drains are laid and jointed, but before they are embedded in concrete, or before the drain trenches are filled in. The lower end of the drain, as it enters the disconnecting chamber, is plugged by means of an expanding screw plug with rubber rim of the size appropriate to the drain, or by means of a strong canvas bag, which can be filled with air under pressure by means of an air force-pump. As soon as the drain is securely plugged, and a cord has been attached to the plug to prevent its being carried away when the water is released, water is allowed to flow into the upper portion of the system until it has risen to the top of an inspection chamber or gulley at the head of the drain. If, after stopping the flow, the water level remains stationary for some minutes, the drainage system under test is sound; but should the water-level fall, there is a defect at some point, and the joints of the drain should be carefully examined for evidence of leakage. It is important to remember that in thus applying the test to a system of drains, air will be imprisoned in the branch drains leading from gulleys or water-closets, if the latter are charged with water. This air is liable to become slowly absorbed by the water when compressed, and thus lead to a fall in the general level of the water, although the drains may be sound. The imprisoned air should be allowed to escape by passing a bent pipe through the water of the trap that retains the air.

In drains of considerable length with steep gradients the head of water pressure in the lowest section of the drain may be considerable; but in testing house drains, at any rate, nothing approaching a bursting strain for well-made and well-jointed stoneware drains is likely to be reached. In testing the drains of very large establishments, however, the system should be tested in sections, and any general test which would place undue strains upon the pipes and joints should be avoided.

In applying the water test to existing drainage, the same methods are applicable; but should a general test show leakage, it will be necessary to test in sections until the leak is sectionally located. There is no difficulty in carrying this out, if there are the proper proportion of inspection chambers, as branch drains can be plugged in the inspection chambers to which they are connected at one end, and tested with water up to the levels of the tops of the gulleys or water-closets with which they are connected at the other. Inspection chambers, which are very often found to be leaky from defective rendering with cement, can be treated separately by filling with water, after all drains entering or leaving them have been securely

plugged. It sometimes happens that an old drain is found to be in a very dirty condition, but water-tight on testing. After the drain has been rodded and cleansed, on further testing it may be

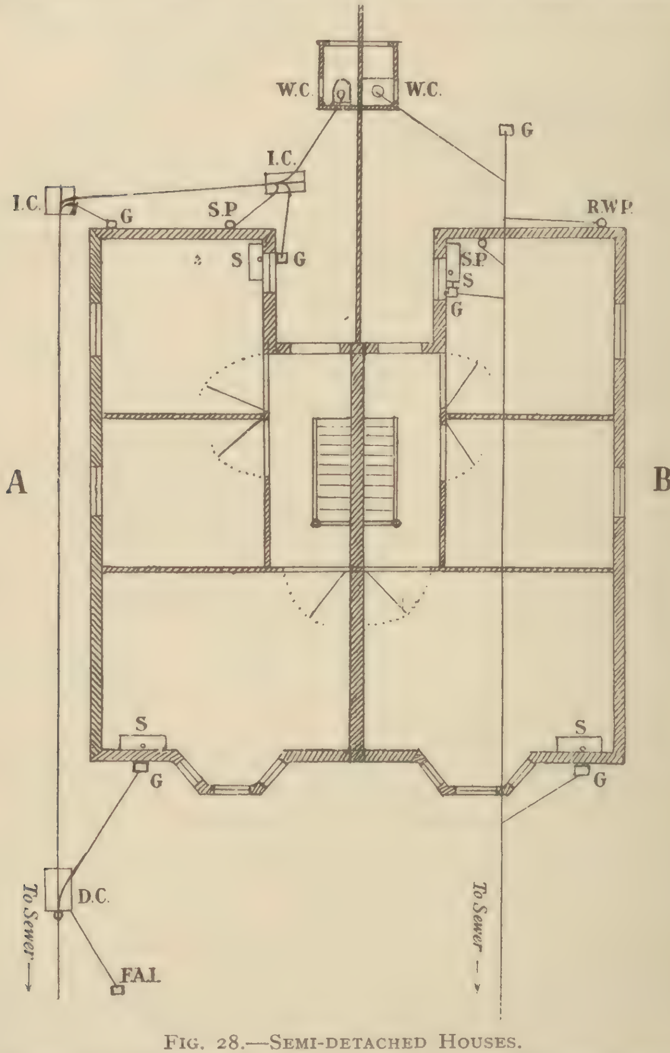

FIG. 28.—SEMI-DETACHED HOUSES.

A, modern drainage; B, old drainage system; D.C., disconnecting chamber; F.A.I., fresh air inlet; I.C., inspection chamber; S.P., soil pipe; G., gulley; S., sink; R.W.P., rain-water pipe; W.C., water-closet.

found to be no longer water-tight, owing to the grease and filth which sealed the interiors of defective joints being washed away in the process of cleansing.

In old drainage systems without any inspection chambers the water test cannot be applied unless the drain is exposed at some point (usually at or near its lower end), and a pipe removed in order that the plug may be inserted. Old drains of this description are very seldom found to be water-tight; and it has been said that the application of the water test to an old drain is liable to damage it and open up the joints. It is very doubtful, however, if the water test carefully applied ever does any injury of this sort even to an old drain. Any soil drain passing under or quite near to a house should be sufficiently sound to pass a water test.

Vertical soil pipes and their water-closet branches may be tested with water, before the w.c.'s are connected, by soldering over the apertures where the closet apparatus is connected, and then filling with water, after plugging the lower end of the soil pipe, or the branch drain from the soil pipe in the nearest inspection chamber. This is a severe test, if there is a great head of water, and one but rarely applied, yet it is withstood by a good lead soil pipe with strong wiped joints.

The Ball Test.—This is applied to new drainage work before the drains are covered in, to ascertain that there are no projections of cement from the joints into the interior of the drain, by passing a spherical wooden ball, ¼ inch less in diameter than the drain, through the pipes from the upper to the lower end.

The Smoke Test.—This test is applied either by means of a smoke rocket or by a smoke machine. The test is usually applied to both underground drains and vertical soil pipes, or drain ventilating pipes, at the same time. The disconnecting chamber, or inspection chamber at the lowest point of the drain, is uncovered, and the smoke rocket after ignition is inserted into the drain delivering into the chamber. The rush of smoke from the rocket forces the air upwards through the drain, and where there is a good upward draught, the smoke will shortly be observed issuing from the top of the soil pipe or the drain ventilator. As soon as the smoke issues freely from the outlet this should be closed by means of a plug or by a wet cloth, and at the same time the drain should be plugged where the rocket is inserted, or the cover to the inspection chamber should be replaced to prevent reflux of smoke at this point. In this way the whole length of drain and soil pipe and soil-pipe ventilator can be charged with smoke confined under very slight pressure. If there are any defects in the pipes or in their jointing, smoke will escape at such points, and will generally make itself evident either to sight or smell, according as to whether the defect is exposed to view or concealed beneath the ground or in walls and casings. In carrying out the smoke test, particular care is necessary to insure that all traps connected with the drain or soil pipe under test are properly charged with water, and that doors and windows facing the spot at which the test is being applied are carefully closed.

In the smoke machine, air is forced by means of a bellows through a metal compartment containing smouldering paper or cotton waste well saturated with oil, and a flexible pipe from the machine leads the smoke into the drain or soil pipe. The machine is rather cumbersome to carry about, but has the advantage over smoke rockets

that the test may be applied under a definite pressure of about 1 to 2 inches of water, and that the flexible pipe can be passed through gulleys or traps on the line of a drain, where inspection chambers do not exist, or the test can be applied from the top of the soil-pipe ventilator in the reverse manner to that usually employed with rockets, where this method is more convenient. The test with the smoke machine is carried out in the same way as previously described for rockets. In either case, where there is no disconnecting chamber to the drain, the water seal in the gulley trap which is nearest to the outlet of the drain is generally removed, and the smoke rocket, or the tube of the smoke machine, is inserted into the bend of the trap. In doing so, however, there is always a possibility that the smoke will pass directly into the sewer, and not traverse the house drain, owing to the absence of a disconnecting trap.

The smoke test is better evidence of defects in vertical soil pipes and ventilating pipes than of defects in underground drains; as, in the case of the latter, although defects may exist, the issuing smoke may not reach the surface of the ground or find its way to any point at which it could be detected either by sight or smell. Escapes from vertical pipes are usually readily detected.

The Pneumatic or Air Test.—This is very similar to the smoke test as applied by a smoke machine, air being forced by means of an air pump into the drain or soil pipe after the top of the soil pipe or other drain ventilating pipes have been securely plugged. A water gauge attached to the pneumatic machine shows the pressure in inches of water; and if this pressure is maintained for a few minutes, it is evident that the system under test is air-tight. The nozzle of the machine passes through an expanding screw plug or pneumatic bag, which makes an air-tight joint with the drain or pipe into which the nozzle is inserted. The test is a severe one, as the very smallest pin-hole defect will present an aperture for the escape of air, sufficient to prevent a pressure of an inch of water being maintained with the pipes under test. It suffers also from the drawback that there is nothing to indicate the exact position of the defect, since the escaping air is both colourless and odourless.

The Chemical Test.—This is usually applied by means of grenades or small glass capsules containing a composition of phosphorus and asafœtida. When the containing glass is broken and the composition comes into contact with water, a slight explosion takes place, and dense white fumes having the characteristic smell of asafœtida are evolved. These fumes escape through defects in the drain or pipes, and so give evidence of leakages, which are recognized by the sense of smell. In testing underground drains by this method a certain time (15 to 30 minutes) should be allowed to elapse before deciding that there is no evidence of defects, as the odour may take a considerable period to travel from the defective drain to any point at which its presence could be appreciable. In using the grenades, one or two may be wrapped up in blotting paper, broken by a sharp tap, and then thrown into the w.c. basin on the highest floor, the basin being immediately flushed, so as to carry the broken capsules to the drain side of the w.c. trap; or the same result may be attained in Kempe's apparatus, the grenade or capsule being floated through

the trap of the w.c., and then broken by a sharp pull on a string which releases a spring.

There is a method of repairing leaky drains, *in situ*, without opening the ground, which may be applied in suitable cases. The drain is first cleansed, and then a small apparatus containing Portland cement under pressure is passed several times through the drain. As the apparatus passes any leaky point in the drain, the liquid cement escapes at this point and fills the leaky joint, etc. Time is then allowed for the cement to partially set, when a swab is drawn through the drain to remove any projecting pieces of cement. The drain is thus treated in sections, which are temporarily disconnected, and finally a water test is applied to the whole. For old and defective drains from which there has been much leakage it is more sanitary, and often more economical, to remove the old pipes and the contaminated earth surrounding them, and to replace with sound pipes and clean earth.

Stables.

The proper paving and drainage of stables is important, as dampness and foul air are very injurious to the health of horses. The floors of stables should be paved with a small hard brick, such as that known as adamantine clinker, with chamfered edges set in cement, such bricks being impervious to water and small enough to give a foothold to the animals. The floor should have a gentle slope of about 1 inch in 10 feet, from the heads of the stalls towards a cement drainage channel constructed to convey liquids outside the stable to a gulley in the stable yard. These channels should be covered with iron gratings flush with the floor, easily detachable for the purpose of cleansing. If horse and mare pots are considered preferable to channels, they should be connected to drains, which are led outside the stable to discharge into the back or side inlet of a deep gulley. Inasmuch as a good deal of straw or other material used for litter is apt to pass away with the stable drainage, the gulley receiving those liquids should be a Dean's silt gulley with removable bucket for collecting solid particles (*vide* fig. 29).

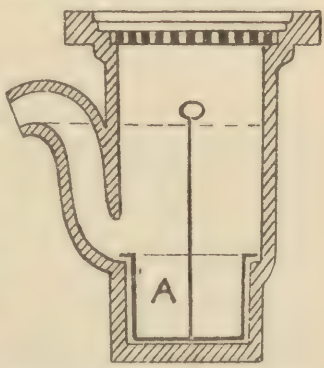

Fig. 29.—Dean's Silt Gulley.
A, Cast-iron receptacle to lift in and out.

For storing stable manure, whilst awaiting removal, the best

receptacle is an open wire cage, which allows the free play of air over the surface of the refuse, and thus prevents heating and fermentation in the interior. Sunken dung pits are generally a nuisance, as they favour fermentative changes; they should be abolished in favour of open wire cages resting on a cemented surface in the stable yard.

Peat moss, dried and compressed, is now largely used as litter instead of straw, especially in cab and omnibus yards. It is more absorbent than straw, and consequently keeps the stables where it is in use very dry. If used too long, it becomes highly impregnated with urine, and gives off most offensive effluvia. In cab and omnibus yards the peat moss manure is generally very rank and stale before it is removed from the stable, and when stacked in heaps and subsequently thrown up into carts, the nuisance is very great. It is in these cases especially that carts or vans should be used to receive the manure directly as it issues from the stalls of the stables, so that when the van is filled it can be drawn away without further disturbance.

Mines.

Although many conditions are imposed which aim at safeguarding the miners of this country from accidents, and although much has been done in recent years to diminish the incidence of pulmonary complaints among miners by reducing dust and noxious gases arising from drilling and blasting operations, comparatively little has been done in reference to those other sanitary precautions which are necessary in order to guard against the risks of spread of enteric fever and ankylostomiasis.

That the danger which the miner runs of infection of enteric fever is real, and at times leads to outbreaks of disease in this country, has been testified to on several occasions.

The reports upon ankylostomiasis in Westphalia and elsewhere provide almost a voluminous literature on the prevalence of this disease in hot, damp mines; and among the most valuable of these reports, and one which has also a topical interest, is Dr. Haldane's Report to the Home Secretary on an outbreak of the disease in a Cornish mine, where ankylostomiasis remained long in evidence.

The sanitary conditions underground have often been demonstrated to favour the spread of both of these diseases, and it

is alike in the interests of mine owners and miners that more precautions should be taken to guard against them. The capital expenditure involved would return a satisfactory rate of interest by maintaining a higher level of production.

A mine that would satisfy the full demands of hygiene in respect of the danger associated with miners' excreta should have sufficient and suitable provision in the workings for the collection, removal, and disposal of all dejecta. It should be remarked here, however, that in the case of coal mines, where the bed is approximately horizontal, there is little objection to the use of the "goaves" or "wastes." Miners should realize the importance of taking suitable precautions underground with reference to their dejecta; they should also endeavour to acquire the habit of defæcating morning or evening before descending, so far as possible, and should only defæcate below when really necessary; and in order to promote this practice privies or water-closets should be provided near the pit mouth. Miners should be informed of the necessity of being careful with reference to the food consumed underground; this should be kept covered in tin cans or paper, and only handled through paper, and the hands should be kept out of contact with the mouth. The men should wash and change clothes before partaking of food upon their return home after work, and to promote this practice spray baths and dressing-rooms should be provided near the pit mouth. Miners very rarely drink any mine water (except in some exceptional circumstances abroad); they take their drink down into the mine with them; but the men should realize that under no circumstance is it safe to drink mine water, and that if such water is used for rinsing the hands it can never sufficiently cleanse them. Stagnant water in the working should be reduced to a minimum; and where there is running water the channels should be kept clear and the water not allowed to "pond" in places through waste matter blocking up the channels.

No new hand should be employed without previous medical inspection, and a careful inquiry into his previous infectious disease history. If he has recently had enteric fever, or if there is a possibility that he may be harbouring the ankylostoma, his dejecta should be first examined bacteriologically; and all cases of illness should be promptly reported to the manager or agent. Provision should be made at the nearest bacteriological laboratory for samples of dejecta to be examined.

The special rules relating to the dejecta which have been made under the Metalliferous Mines Regulation Acts, 1872 and 1875, are to the following effect:—

(5) The owner, agent, or manager shall cause a sufficient number of suitable sanitary conveniences to be provided above and below ground in convenient places for the use of the persons employed, and to be constantly kept in a cleanly and sanitary condition, and no person shall relieve his bowels below ground elsewhere than in these conveniences. No person shall soil or render unfit for use in any way any convenience or sanitary utensil or appliance provided for the use of the persons employed. Pump cisterns, sumps, and water accumulations in the mine shall not be indirectly used for the purpose of a sanitary convenience.

(6) It shall be the duty of the owner, agent, or manager to see that plant, material, and other things necessary to enable the above rule to be carried out are provided and maintained in working order and to appoint sufficient competent officials to enforce the requirements of the rules, and for this purpose to assign to each his respective duties.

Sewers.

Sewers are underground channels designed to receive and convey away by gravitation the rainfall and waste waters of the town, and, where the water-carriage system has been adopted, excretal refuse as well. In former times, and in some towns at the present day, if a river or stream passed through or near a town, the sewers took the shortest available course to the banks of the stream, and there discharged—each sewer by its own outfall. When it became no longer possible for towns to discharge their crude sewage into streams in this manner, intercepting sewers of large size had to be constructed to receive the sewage of the tributary sewers and conduct it outside the town.

As we have already seen, brick sewers, as originally constructed, perform a double function; they are land drains as well as sewers. By permanently lowering the level of the subsoil water in towns, these sewers have had an important effect in improving the health of the inhabitants.

But the beneficial influence of sewers acting as drains has an undoubted drawback, viz., that drain sewers will readily permit of foul liquids percolating out of them, through their walls, to pollute the surrounding soil and contaminate ground water and ground air in the neighbourhood. That such escape of foul water does take place is plainly shown by the fact that in London, with its drain sewers, all shallow well waters have been found to

be polluted with sewage, and the wells have in consequence been closed. It is now the practice of all engineers to construct sewers as far as possible water-tight, and to provide other means for draining the soil.

The Combined System.—In this system the sewers are designed to receive the rain—or such part of it as does not evaporate or is not retained by the soil—falling over the area covered by the town, as well as the sewage proper. The amount of evaporation depends largely on the temperature of the air; but even in summer it is found in towns, where a large part of the surface exposed to rainfall consists of roofs and paved surfaces of yards, courts, and streets (especially also where there are steep gradients), that from one-half to three-quarters of the rain falling reaches the sewers. It is therefore necessary to construct the sewers of sufficient size to take a large part of the rain falling during heavy storms, such as $\frac{1}{2}$ inch of rain in one hour in towns, and $\frac{1}{4}$ to $\frac{1}{3}$ inch in the suburbs; otherwise, if no storm overflows are provided, the sewers in low-lying districts are overcharged, and cellars and basements are flooded. In London the intercepting sewers were constructed to receive $\frac{1}{4}$ inch of rain over the whole area sewered in twenty-four hours (including subsoil water); but storm overflows direct into the Thames relieve these sewers during heavy storms. When a storm occurs after a time of drought, the sewers are flushed of accumulated deposit, and the sewage which first escapes by the storm overflows is often very strong and foul, and productive of nuisance in the river. At high-water, too, the storm overflows are tide locked, and then low-lying districts may be flooded.

This principle of the interception of sewage is also commonly practised in seaside towns where the original sewers have been given a direct course to the sea, and the escaping sewage gave rise to offence. The intercepting sewer running along the seashore picks up the original sewers, and conveys the sewage to its outlet some distance away from the town. Such a main outfall sewer discharging into the sea should terminate below the water-level, even at low tide, and should have the outlet protected by a flap valve.

To prevent deposits, sewers should be rendered self-cleansing by being constructed with a sufficient gradient, and of a size suitable to the volume of sewage which they will ordinarily be required to carry.

In modern systems of sewerage, the sewers are laid in straight lines with manholes at every point of change of direction. The inspection and cleansing of the sewers is much facilitated by such an arrangement. The best form of sewer in all cases in which the volume of sewage undergoes fluctuation is the egg-shaped, the small end of the egg being downwards. In this form there is a greater depth of sewage and less contact with the walls of the sewer (and consequently less friction) than in any other form. For outfall sewers, in which the volume of sewage to be conveyed is large and uniform, Mr. Baldwin Latham advised the circular form, as it is cheaper and stronger when constructed. Up to 18 inches internal diameter, sewers should be circular in section; and for these small sizes, stoneware, cement, or concrete pipes are better than sewers constructed of brick. Iron pipes and patent joints in stoneware pipes are often used in damp sites. No public sewer should be less than 9 inches in diameter, owing to the risk of smaller pipes becoming obstructed and stopped up by articles improperly introduced into the house drains.

Sewers of unequal sectional area should not join with level inverts; but the bottom of the lesser sewer should have a fall into the main at least equal to the difference between the diameters of the tributary and the main sewer.

Well burnt, tough, impervious bricks, or glazed firebricks, should be used in the construction of sewers, especially in the construction of the lowest segment or invert of the sewer, which is the part most liable to wear and erosion from the passage of stones and grit in the sewage over it. For the smaller sewers suitably curved bricks only should be used. Sewers under 3 feet in diameter, when laid in good ground, may be constructed of 4½-inch brickwork. When laid in bad shifting ground, or for larger sewers, 9-inch brickwork should be used. The mortar used in jointing the bricks should be made of the best Portland cement and fine sharp sand. Suitably curved stoneware blocks are sometimes used for the inverts of sewers, their smooth hard upper faces forming an excellent floor for the sewer.

The Separate System.—Where it is intended to convey away sewage proper only, storm, surface, and subsoil waters being separated, the sewers need be only of small size. Under such circumstances glazed stoneware pipes, jointed with Portland cement, are generally used to form the tributaries, whilst the

outfall sewer is constructed of brickwork. Cement or silicated concrete pipes have been used, especially in Germany, instead of stoneware pipes. They are said to be less brittle, to withstand extremes of climate, and to resist the chemical action of the sewage better than stoneware pipes. Under the separate system, the sewers, of whatever material, must receive water-closet sewage and waste waters only; all rain-water from yards, or areas, must be conveyed by separate pipes into surface channels at the sides of the streets, when the gradients are sufficient, or into underground channels constituting a system of drains quite distinct from the sewers. At convenient points the surface channels or underground drains should discharge into the stream or river which forms the natural drainage bed of the locality. The drainage of the subsoil should be effected by agricultural tile drains laid in the same trench, but above the sewers, and diverted into the watercourses at all suitable points.

The advantages of the separate system are: (1) The volume of sewage to be conveyed outside the town is small as compared with that to be dealt with by the combined system; its daily or seasonal fluctuations, and the total quantities to be dealt with, can be calculated approximately from the population and water supply (points of great importance where the sewage has to be pumped to the outfall, or to be purified before being discharged); (2) the sewage is uniform in composition because protected from dilution with storm waters, and its purification and utilization day by day are therefore undertaken with much less difficulty than is the case with sewage which is sometimes strong and at others very weak from admixture with rain and subsoil waters; (3) the sewers, being small and having smooth walls, are more frequently flushed, and there is less tendency to deposit, with formation of foul gases, than in the case of the larger brick sewers.

The disadvantages are: (1) That every house must have two drains or two sets of pipes—one for sewage and the other for rain-water; and this gives rise to mistakes on the part of builders, who occasionally connect the pipes with the wrong system; (2) that the surface water from yards and streets is often too foul to admit into a stream, especially when a storm succeeds a period of drought, unless the yards and streets are constantly cleansed and well scavenged; (3) that the flushing effect on the drains and sewers of storm waters is lost; (4) traps and drains

receiving storm waters only tend to become unsealed in the dry summer weather. It is, however, sufficiently obvious that these disadvantages in no way counterbalance the undoubted advantages of the separate system.

Inspection, Flushing, and Ventilation of Sewers.

In any system of sewerage it is necessary to provide means of access to the sewers for their cleansing and for the removal of accumulations of deposit. Manholes are shafts sunk from the surface of the road to the sewer by which the sewer-men can descend. They are constructed of brickwork, and provided with a locked iron door at the street level. In streets where there is much traffic, the shaft is sunk from the footway perpendicularly for a short distance, and then carried down by means of steps to the side of the sewer. In other cases the manholes are sunk from the middle of the road to the crown of the sewer. They have also a variety of other uses; they are used as points of junction between tributary pipe sewers and the main sewer, curved channels being constructed in the floor of the manhole; and they are also the points at which flushing gates may most advantageously be fixed in brick sewers.

Flushing gates are sluices made to fit the whole or part of the sectional area of a sewer. When in position they dam back the sewage in the sewer above, and on being raised, or liberated, the sewage so stored rushes forwards and effectually flushes the sewer below. Self-acting gates are often used for this purpose. The gate being hinged below its centre, the pressure of the sewage on that portion of the gate which is below the hinge fixes it in position. As the sewage rises, the upper portion of the gate is likewise exposed to the pressure of the sewage, and presenting a larger area than the part below the hinge, a point is at length reached when the gate tilts, assuming a horizontal position, and the sewage escapes.

The *ventilation of sewers* is a matter of importance, as the health of a sewered district probably depends to some extent on the efficiency of the sewer ventilation.

The most offensive gases are given off from sewers in which deposit forms, such as the old-fashioned brick conduits with flat bottoms, or oval sewers in which a portion of the invert has sunk below its proper level, or sewers which are too large for

the volume of sewage they ordinarily convey, and in which the deposits and slime, formed on their floors and sides, are not removed by flushing. Outfall sewers in which sewage is, for any reason, backed up and stagnant during a portion of the day are also liable to become sewers of deposit. The deposit rapidly putrefies, giving off offensive gases, which escape through the nearest ventilator; or should the sewer be insufficiently ventilated, the foul gases find an exit through house drains and traps into the interior of houses.

In all sewers, owing to the constant variation of the flow of sewage through them, some deposit forms on their sides, which, being alternately wet and dry, rapidly putrefies and parts with its putrefactive ferments to the sewage flowing by. In pipe sewers there is less tendency to deposit than in brick sewers of large diameter, owing to the smooth internal surfaces of the pipes, and to the greater frequency with which they are washed, as pipe sewers are more often running full or nearly full than brick sewers.

Natural ventilation of sewers, by which movements of air in them are produced, is due to a variety of causes, the most important of which are:—(1) Where there is a strong and rapid stream, a current of air is produced which is in the same direction as the sewage stream, and of proportional velocity. Most of the openings into the sewers will be inlets for fresh air (drawn in by the current of air beneath), which finally escapes through the outfall sewer. (2) During the cold months of the year the temperature inside a sewer is, owing to the warmth of the sewage, higher (average about 7° F.) than that of the external atmosphere, consequently the warmer sewer air tends to rise and to be replaced by the cold external air. During the warm months of the year the temperature of the sewer is by day often considerably cooler than the external air. In spring and autumn the temperatures inside and outside are more nearly equal. (3) The air of sewers is generally saturated with moisture, and therefore lighter as a rule than the general atmosphere outside, both in summer and winter. For this reason sewer air generally tends to rise up from any openings into the sewer. (4) The passage of hot liquids from houses and from factory boilers causes a rise in the temperature of the sewage and expansion of the sewer air. Blowing off steam from boilers into sewers causes a great rise of pressure, and unless ample ventilation is provided house traps will be forced. (5) During the early part of the day, the volume of sewage in the sewers increases rapidly to a maximum, and air is consequently slowly expelled, to be replaced by inflowing air as the level of the sewage falls. The rising of the tide in an outfall sewer, not protected by a tidal valve, will also displace air, but the displacement is so gradual as to be almost inappreciable. Where

storm waters are admitted into the sewers, sudden heavy rainfalls exert a marked influence in expelling air, which is somewhat counterbalanced by the aspirating effect produced by the flow of air in the direction of the current. (6) Sudden falls of barometrical pressure cause air and gases dissolved in the sewage to be given off. (7) Sudden variations in temperature of the external air produce variations in pressure of the sewer air. A high temperature favours decomposition of the sewage and evolution of gases.

Openings into the crowns of sewers from the surface of the roadway should be made at distances of not more than 100 yards apart. Some of these will act as inlets, and others as outlets, and the pressure of air in the sewer will at no time be able to rise sufficiently to force the traps on house pipes and drains.

There are objections which apply to the method of ventilating sewers by means of the soil pipe ventilators of houses, as when this method is carried out there must be no disconnecting traps to the house drains and fresh-air inlets to the drains cannot be fixed. Sewer air escaping in large volumes near dormer windows might also cause a serious nuisance. Where a disconnecting trap is fixed on the house drain, a 4-inch pipe may be carried up to the ridge of the roof from the drain on the sewer side of the trap, its end being left open; and it will be found useful as an exit for sewer air when used in combination with road ventilators. But it is needful to bear in mind that where rain-water is admitted to the sewers, during heavy rainfall, when ventilation is most required for affording a safe exit for suddenly displaced sewer air, house drains, or any part of them, are often useless for this purpose, as their openings into the sewer may be sealed by the height at which the sewage is flowing in the sewer.

The best form of street ventilator is the shaft sunk from the middle of the roadway to the crown of the sewer. Beneath the grating at the surface of the street should be placed a dirt box to catch gravel and mud, which would otherwise fall into the sewer, a space being left around the box for the passage of air. The dirt box should be capable of removal from the surface of the road. Ventilators may also be constructed in connection with manholes. A shaft is sunk for a short distance by the side of the manhole, openings being made between them for the passage of air. Mud and gravel fall to the bottom of this shaft, from which a pipe conducts the water to the sewer beneath. The air which escapes from the sewers by these street ventilators

is rapidly diluted with fresh air; and, from their position in the centre of the roadway, there is the least chance of offence to foot passengers or of foul air gaining entrance to houses. In narrow courts and streets, especially at the upper or dead ends of sewers, the surface ventilators should be replaced by shafts carried up from the crown of the sewer to above the tops of houses; for it is desirable to avoid any risk of foul sewer air collecting in stagnant courts and streets surrounded by buildings, in which rapid dilution of the sewer exhalations with fresh air might not always take place. Street gulleys should be effectually trapped, both to prevent mud and sand entering the sewer, and to avoid an escape of sewer air close to the footways and the fronts of houses.

Various processes (such as Reeves') have from time to time been patented for deodorizing the sewer air escaping from street ventilators by bringing it in contact with gases, generated by the automatic and gradual mixing of different chemical solutions. More recently a method of cremating the sewer air, by passing it over or through a gas flame placed in a chamber at the top of the ventilator, has been tried. By this method the escaping sewer air is heated, possibly even to the point of sterilization, whilst the combustion of the gas tends to create an artificial draught up the sewer ventilator. There can be no question that any general adoption of such systems is undesirable. If the sewers are well laid and self-cleansing, they are not required. Should the sewers be so old and dilapidated as to be generally offensive throughout a district, it would prove more satisfactory and far more beneficial to the public health to reconstruct them on modern principles than to inaugurate a system of concealing the effects without attacking the cause.

The Disposal of Sewage.

The disposal of the sewage of a town or district is often a most difficult problem to solve. Since the Rivers Pollution Prevention Act became law in 1876, it has been illegal to discharge crude sewage into a *stream*—this term including rivers, streams, canals, lakes, and watercourses, other than watercourses mainly used as sewers, and also the sea to such extent, and tidal waters to such point, as may after local inquiry, or on sanitary grounds, be determined by the Local Government Board. It is greatly to be regretted that this Act has in many parts of the country entirely failed to prevent the continued pollution of streams, from which the community has already so largely suffered.

Where sewage is discharged into fresh running water and at

once largely diluted, it becomes in course of time to a great extent purified. Distributed through a large volume of river water, the organic matters are oxidized (through the aid of nitrifying bacteria) by the oxygen dissolved in the water and by that given out by minute water plants (algæ, diatoms, and desmids), and are also assimilated by minute animals (infusoria, rhizopoda, entomostraca, anguillulæ, etc.). They are thus purified, or got rid of, without the occurrence of putrefaction and the formation of offensive gases, which must occur when the sewage is not sufficiently diluted with fresh water and the temperature of the air and water is high—the growth of fermentative bacterial organisms then taking place to such an extent as to cause putrefaction. Putrefactive bacteria will no doubt in time break up complex organic matters into their constituent parts, and thus purify sewage; but the process is one productive of nuisance and injury until the ultimate effect is attained.

In the case of tidal sewage-polluted rivers, the Reports of the Royal Commission on Metropolitan Sewage discharge show that the only true sources of dilution of the sewage are the land water entering from above, and the sea water from the mouth of the river. During dry weather, when the quantity of land water is slight, the displacement of the sewage towards the sea is very slow (about a quarter of a mile daily in the case of the Metropolitan sewage); so that the sewage discharged on any particular day oscillates up and down the river with the tide, and is continually receiving fresh increments. The sewage, too, that is discharged after high water on an ebbing tide will be carried up by the flowing tide above the outfall; and when neap tides are giving place to spring tides, the whole volume of discharged sewage is carried up higher and higher above the outfalls every day as the spring tides increase. The consequence is that at such times the sewage may be carried in the river up to or above the town so discharging its sewage.

The effect, too, of the sea salts in estuary water is to cause a precipitation of organic matters and a deposit of mud, whilst the oxidation and purification processes are delayed by their presence.

If the volume of sewage discharged is relatively small to the volume of water in the river, the sewage will in time be purified; but such water can under no circumstances be a proper source of supply for drinking water.

Under certain circumstances crude sewage may be discharged directly into the sea without risk of nuisance and offence. If the sewage can at all times be borne away from the shore out to sea, it becomes mixed with an immense volume of water and rendered harmless. The danger is that sewage may be cast up by the tide on the foreshore, or borne along by currents the whole length of the sea front of a town. To avoid such an event, the outfall must be chosen at such a spot that the sewage, at whatever state of the tide it may be discharged, shall be carried by currents, where such exist, straight out to sea, or at least in a direction away from the town. The direction of the currents may be ascertained by means of float experiments.

The outfall sewer must open below the level of the water at all states of the tide, and its mouth should be protected by a tidal valve to prevent sea water entering it. The prevailing winds should also be studied, to prevent the possibility of floating fæcal matters being blown back on to the beach. If the town lies at a low level, so that its sewers are tide locked for several hours of each tide, tanks must be constructed to retain the sewage which accumulates at such periods; or a certain length of large oval tank sewer must be built to serve the same purpose.

Tank sewers, however, are very generally productive of nuisance. The tide-locked sewage stagnates in them, and a copious deposit of sediment takes place which gives rise to the formation of foul gases. In such cases no amount of ventilation suffices to obviate the nuisance. It is better to have recourse to steam pumping at the outfall, or to use Shone's Pneumatic Sewage Ejectors to relieve the sewers of their accumulated sewage.

Shone's system is now in operation at several towns lying on low flat ground, and has been found very beneficial in preventing the evils which result from absence of proper sewer gradients.

The motive power is compressed air, which is conveyed from a central station by wrought-iron pipes to the cylindrical reservoirs or "ejectors," which are situated in chambers beneath the streets at different parts of the town, and receive the sewage from the street sewers. When the ejectors are full, a valve opens and compressed air is admitted by means of a float acting on a counterpoise lever, and the sewage is thereby forced out into a gravitating sewer at a higher level. A ball valve in the pipe sewer entering the "ejector" prevents the sewage from being forced backwards by the compressed air; and as the sewage is discharged and its level sinks in the "ejector," the sinking of the float closes the valve of the compressed air tube,

and a fresh charge of sewage can then enter. The great advantage of the system is that good gradients can be given to the sewers, for the ejectors are placed at sufficient depths below the surface of the ground to permit of house drains and street sewers, with which they are connected, having a good fall; and the sewage can thus be carried away and forced out of the town in a fresh condition. In addition, no storage is required as in ordinary pumping, for the rate of working of the ejectors varies with the rate of flow of the sewage into them, although the air compression machinery at the central station works nearly uniformly.

Liernur's pneumatic system of sewage removal and treatment is carried out at Amsterdam and Trouville. It is claimed to be especially applicable in towns where the water supply is limited, and where the ground is too flat to admit of good sewer gradients. There is an air-tight system of sewers, the contents of which are drawn into closed chambers fixed in different parts of the town, by means of a powerful air pump at a central station. From these chambers the sewage is sucked into a steam concentrator at the central station, and is there heated to about 100° C. after the ammonia has been fixed by the addition of sulphuric acid. The dried sludge ("poudrette") finds a ready market as manure. It appears that the pipes tend to get clogged, but otherwise the system works well.

The Purification and Utilization of Sewage.

It can be safely said that in this country no stream or river should ever receive crude sewage; for so numerous are the towns on the banks of nearly every stream, that, although the sewage of one town might be purified after a certain run, it would be quite impossible for any stream to purify the successive sewage discharges from every town on its banks.

Subsidence, Straining, and Precipitation.

By allowing sewage to settle in tanks of about 6 feet in depth, a portion of the suspended matters subsides to the bottom and a more or less clarified liquid can be decanted from the top. By straining crude sewage through beds of ashes or charcoal, the suspended matters are removed; but the filters speedily become clogged, and require frequent renewal at great expense.

Certain chemical substances, when mixed with sewage, cause a more rapid and copious precipitation of the suspended matters than can be effected by subsidence alone. The number of chemicals that have been used or advocated for this purpose is enormous, as may be seen on inspection of the specifications of patents taken out to protect the inventors of such processes.

Lime—as lime water or milk of lime—sulphate of alumina, and protosulphate of iron, are the substances now most commonly used as precipitation agents. Lime is the most frequently employed—either alone or in combination with sulphate of alumina or iron.

The precipitating effect of lime on sewage is due partly to its combination with carbonic acid, forming an insoluble carbonate of lime, and partly to its combination with some of the organic bases of sewage. These substances subside, carrying with them most of the suspended matters in the sewage, and sink to the bottom of the tank, forming the sludge, whilst a more or less clear liquid remains above. If too much lime is added, the sludge and supernatant liquid, being strongly alkaline, tend soon to undergo decomposition. The proportion of lime usually added to sewage of average strength is about 12 grains to the gallon of sewage.

The precipitating effect of sulphate of alumina on sewage is due to combination of the sulphuric acid with lime and other bases in the sewage, whilst the alumina hydrate is precipitated in a flocculent condition, entangling and carrying down in its course most of the suspended organic matters. The crude sulphate of alumina used as a precipitant is acid, and reduces somewhat the alkalinity of the lime when this material is employed in combination with it. For treating sewage of medium strength the quantities need not exceed 5 grains of lime and 5 grains of sulphate of alumina per gallon of sewage.

When protosulphate of iron is added to alkaline sewage or to sewage which has been already treated with lime, a highly flocculent hydrated protoxide of iron is formed, which falls to the bottom of the tank, carrying suspended organic matters with it. The iron salt is also a powerful antiseptic, checking further putrefaction of the sludge and effluent, when used in sufficient quantity. But its use is attended with the disadvantage that the mud banks of the stream, into which the effluent is discharged, are blackened by the formation of sulphide of iron. When used with lime, protosulphate of iron should be added in the proportion of from 2 to 5 grains per gallon of average sewage. The London sewage is thus treated, the lime and iron being added in the proportion of 5 and 2 grains, respectively, to the gallon of sewage.

The combination of iron with alumina is also effective as a

precipitating agent, and both enter into the composition of two well-known sewage precipitants—Ferrozone and Aluminoferric.

These three precipitating agents—lime, sulphate of alumina, and protosulphate of iron—cause a more or less complete deposition of the suspended matters in sewage, and also remove the grosser sewage odour from the effluent; but they have very little effect in removing from the sewage the organic matters in solution. Sulphate of alumina is said to have the effect of removing 5 per cent. of the dissolved organic matters of sewage, but lime and iron remove practically none. The matters precipitated from sewage, which form the sludge at the bottom of the tanks, are comparatively worthless, whilst the bulk of the valuable manurial ingredients remains in the effluent.

To insure the most complete clarification of the sewage liquid by chemical precipitants, the following conditions must be satisfied: The sewage must be fresh and undecomposed, and the larger solid bodies should be strained from it before the admixture of the chemical precipitants. The chemicals must be added to the sewage immediately before it arrives at the tanks, and must be well stirred and mixed up with it by means of rotatory mixers. There must be sufficient tank accommodation. The Local Government Board requires that the tanks must be capable of holding the dry weather flow for 24 hours. The tanks are often arranged in series, so that the sewage may pass slowly but continuously through two, three, or four tanks before the supernatant liquid escapes into the effluent channel, which should be kept scrupulously clean. The tanks must be at least 4 feet deep, and the effluent passing out of a tank should flow over a weir not more than ½ inch below the surface into the next tank of the series, or into the effluent channel. After a certain period of continuous working, the flow of sewage through the series must be discontinued, and the sludge allowed to settle, the clear liquid above being drawn off through float valves into the effluent channel. Sometimes the chemically treated sewage is not allowed to pass slowly from tank to tank in series, but each tank is filled separately. When full the flow is stopped and the sewage is kept at rest for from 2 to 4 hours (according to its strength), so that it may deposit its sludge. The clarified supernatant liquid is then drawn off. There should be a double set of tanks, in order that the treatment of the sewage may continue

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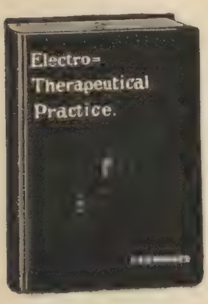

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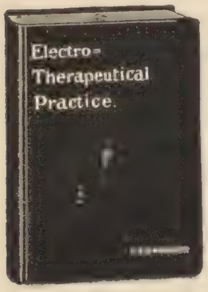

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whilst the sludge is being removed. The sludge must be frequently removed or it will putrefy, and black masses will be disengaged, which, rising to the surface, give off foul gases. The tanks, when emptied, must be thoroughly cleansed before being refilled. A form of precipitation tank (such as the Dortmund tank) with a conical bottom has the advantage over the old-fashioned flat-bottomed tank in so far that it permits the sludge, which falls to the apex of the cone, to be removed without first drawing off the supernatant effluent.

Occasionally substances which act as deodorants or antiseptics are added to the sewage as well as the chemical precipitants. The addition of manganate of soda and sulphuric acid to chemically treated sewage has been recommended by Mr. Dibdin in order to promote oxidation. Another deodorizing method is that known as the Amines process. The sewage is treated with milk of lime and with a small quantity of herring brine, which contains a certain percentage of the compound ammonia termed methylamine. This substance acts as a deodorant and antiseptic, so that the effluent undergoes no secondary fermentation; whilst the sludge is so far deodorized that it can be dried in pits exposed to the air, or on the floor of a drying kiln, without giving rise to noxious effluvia. It is now generally recognized that the use of deodorants as auxiliaries to precipitation processes is advantageous if they do not interfere with the natural agencies of purification.

In the Hermite system sewage is treated with partially electrolyzed sea water. The electric current, generated by a dynamo, is passed through sea water contained in a galvanized iron tank, between electrodes of zinc and platinum. In doing so, magnesium chloride is probably decomposed, forming a disinfecting fluid of a strength equal to 0·75 gram of chlorine per litre. The active principle of the fluid may be an oxygenated compound of chlorine, hypochlorous acid, or hypochlorite of magnesia. The solution has the smell of a weak solution of bleaching powder. It contains no free chlorine. It is claimed for the process by its inventor that the solution produces an instantaneous decomposition of fæcal matter in sewage, and effectually sterilizes the sewage, but the experiments conducted at Worthing do not bear out these assertions. A solution of bleaching powder in water would probably be equally effectual, and much cheaper.

In the oxychloride process sea water or water containing 10 per cent. of common salt is electrically decomposed in an electrolyzer having a large superficial area of electrical surface, which permits the use of a high density current at a low voltage. The resulting liquid contains 0·2 per cent. of available chlorine. From Dr. Rideal's experiments at the Guildford Sewage Works it appears that when mixed with appropriate volumes of sewage effluents the oxychloride solution very largely reduces the total number of organisms present in the effluent, and practically eliminates *Bacillus coli communis*.

The suspended matters, or sludge, of sewage being deposited at the bottom of the settling tanks, the questions arise: What is to be done with the clarified sewage ? and, How is the sludge to be got rid of ? No nuisance will result if the effluent is discharged into a quickly running stream or river, whose volume is at least ten times greater than that of the effluent, and which is not used below the point of discharge as a source of supply of drinking water. The danger is that during drought in summer the volume of fresh water might considerably diminish; and then, the effluent sewage not being sufficiently diluted, would putrefy and become turbid, forming foul deposits in the bed of the stream, and giving rise to offensive exhalations. This would be especially likely to happen if, at the same time, the temperature of the air was high. By this method, too, all the valuable manurial ingredients of sewage run to waste. The only satisfactory mode of purifying the effluent sewage is to apply it to land, or specially constructed filter-beds.

Where it is not possible to obtain suitable land for this purpose, the partial purification of the effluent from the tanks may be effected by passing through specially constructed filters, consisting of burnt ballast, coke, coke-breeze, coal, or gravel; or the filters may be composed of coarse sand laid upon magnetic oxide and carbide of iron (polarite). The nitrifying organisms in the pores of the filter exert a powerful oxidizing effect on the organic matters dissolved in the effluent, by which these are converted into nitrates and nitrites, etc. The slower the filtration, *i.e.*, the longer the effluent liquid is in contact with the particles composing the filter-bed, the greater is the purification. The filtration must be intermittent to allow of aeration of the filter.

The sludge left at the bottom of the tanks is generally conducted into a well, and thence pumped out in a semi-liquid condition. It then contains from 90 to 95 per cent. of water. It may be got rid of by allowing it to flow, or by forcing it up, in this liquid condition, along raised carriers on to land, into which it is subsequently dug, thereby eventually becoming incorporated with the soil. This was the method pursued at Birmingham, the sewage being treated with lime, and the effluent from the tanks being purified by irrigation over the soil of the sewage farm. If the semi-liquid sludge is allowed to dry by exposure to the air in pits, it generally causes a nuisance, so that it is the usual practice to press part of the moisture out of

the sludge by hydraulic filter presses, by which a solid cake, containing from 50 to 60 per cent. of moisture, is produced. The pressed sludge can be stored up without causing any nuisance, and sold or given away according to the demand for such sewage manure. It may be further dried by heating in drying machines, and then ground into a granular condition, when it generally contains some 20 per cent. of moisture. In this condition the manure is far more suitable for application to land than in the form of the coherent masses which issue from the filter presses.

The Biological Purification of Sewage.

The chief natural agencies concerned in the purification of organic matter are micro-organisms. It is almost entirely due to such organisms that organic matter—whether it be fæces deposited on the surface of soil, or an animal body buried within it—eventually becomes resolved into invisible and harmless gases and mineral ash, for sterilized organic matter remains undecomposed for indefinite periods, so long as sterility is maintained.

Ever since cesspools were employed for the reception of the sewage of a house, it has been noted that the material which is periodically emptied out of the cesspool, or which overflows from it, is a liquid containing very little suspended solid matter. Solid matters in bulk are only encountered near the floor of the cesspool. How is it that a comparatively small cesspool, with an overflow discharging nothing but liquid material for a year or more, does not become filled with the large amount of solid fæcal matter daily entering it? The answer is that micro-organisms in countless myriads are constantly feeding upon this solid matter, and converting it into products which ultimately become dissolved in the liquid part of the sewage. The organisms which effect this change are of many forms, and may be broadly classified into three groups:

1. Those which work in the absence of oxygen (anaerobes).
2. Those which work in the presence of oxygen (aerobes).
3. Those which are capable of working either in the presence or absence of oxygen (facultative aerobes).

Our knowledge of the last-named group is not sufficient to enable us to speak with certainty as to the part they play in sewage purification, but it is certain that both the aerobes and

anaerobes are concerned in the resolution of organic matter. With regard to these two classes of organisms, there are reasons for believing that the anaerobes are the most efficacious in causing the liquefaction of the solid matter contained in sewage. Prior to attack by these liquefying organisms, the solid organic matter is in a more or less stable condition; but as the result of their life action the complex organic molecule is split up into by-products, which are largely soluble and unstable, and considerable quantities of gases (CH_4, NH_3, CO_2, and SH_2) are evolved.

This *first stage of purification* of sewage is closely analogous to the process of gastric digestion, whereby the organic matter is split up and liquefied; the gelatinous and albuminoid material undergoing a peptonizing process, and the non-nitrogenous substances being reduced, and finally converted into CO_2 and H_2O. As in digestion, also, the element of time is essential. The organisms must not, therefore, be asked to do their work in too short a time, or their activity will be unavailing.

The *second stage of purification* is doubtless largely performed by the aerobes, and, in consequence, every effort should be made to set them their work under conditions favouring an abundant supply of available oxygen. The more or less stable solid organic matters having been broken up, rendered less stable, and thrown into solution in the first stage, are in the second stage converted into the ultimate products CO_2, NH_3, H_2O, and traces of SH_2, nothing ultimately remaining but a trivial quantity of mineral matter, rich in nitrates, chlorides, and sulphates.

It is only in recent years that these natural agencies of purification have been scientifically utilized in the disposal of sewage in bulk, but we have already arrived at such a stage of knowledge that some remarkable results have been achieved. The Royal Commission on Sewage Disposal, appointed in 1898, issued an Interim Report in 1901. In this Report they state that "It is practicable to produce by artificial processes alone, as opposed to land treatment, either from sewage or from certain mixtures of sewage and trade refuse, effluents which will not putrefy, which would be classed as good according to ordinary chemical standards, and which might be discharged into a stream without fear of creating a nuisance." The advantages often gained over the older, or what may be termed the chemico-biological method (in which the sewage solids are first precipi-

tated by chemicals, the comparatively clear effluent being then exposed to biological agencies in filter-beds or in land), are obvious. The almost useless sludge which resulted from the chemical treatment, the collection and ultimate disposal of which entails considerable labour and expense, is reduced to a relatively small bulk (in the septic tank quite $\frac{1}{3}$ of the suspended matters entering the tank are destroyed), and the cost of the chemicals and of their application is also saved. But the greatest gain is doubtless often in the direction of greater efficiency of treatment, which results in a purer and sweeter effluent—one more readily susceptible to the agencies of ultimate purification, and more valuable to vegetable life.

We may now review the various means which have been adopted for utilizing these natural agencies in sewage purification. The first practical attempt to solve the problem was commenced by the Massachusetts Board of Health in 1888. The extensive experiments since made by that Board have established the fact that intermittent downward filtration through prepared filters of suitable material will, by reproducing the most favourable conditions of land filtration, achieve all the good results of the latter on a much smaller area. The experiment showed that the beds need not be of a greater depth than 4 to 5 feet, in order to treat satisfactorily 100,000 gallons of sewage to the acre per diem. In such beds, after a week or two of sewage treatment, the particles of filtering material become covered with thin films (" colonies ") of micro-organisms.

When an installation is provided for the natural purification of sewage, the organisms concerned in the process are planted on the filters, etc., by the sewage itself; but it is not until after the sewage has been applied to the installation for many days that the organisms have become sufficiently developed and differentiated to produce their best effects.

In all natural processes of sewage purification the sewage must first of all be passed through a small grit or detritus chamber in order to retain large mineral particles, which would otherwise find their way into the installation and accumulate there, organisms being of course quite incapable of attacking them.

What is essential in the working of a natural process is for the superintendent of the works to fully appreciate that he has countless colonies of living, working units under his control. Their work must always be regulated according to their powers,

and sufficient and periodical intervals of rest must be allowed them between the regular periods of work. Then, and then only, will they attune their powers to the work they are called upon to perform, and so establish that equilibrium between intake and output which is so easy to maintain and so difficult to regain when once lost.

Mr. Scott-Moncrieff was the first (1891) to suggest a mode of treatment whereby the preliminary liquefaction of solid matters could be brought about in a separate apparatus, and the purification of the matter in solution could be subsequently effected. This mode of treatment of sewage by separating the stages of its purification is doubtless advantageous, seeing that the classes of organisms concerned in the preliminary liquefaction are distinct from those concerned in the subsequent purification, and each class exerts its powers most effectually when kept apart from the other. There is, moreover, evidence that the second stage of purification itself comprises many subsidiary stages, and that special classes of organisms are concerned in these several stages.

Almost all the installations at present in use embody the principle of dividing, to a greater or less degree, the whole process of sewage purification by natural means into these two stages: Stage I. providing essentially for liquefaction of solids, and Stage II. for subsequent purification of the unstable and liquid products of Stage I.

Contact-Beds.—Extensive experiments by Mr. Dibdin from 1891 to 1895 with the Metropolitan sewage led to his advocacy of what is known as the Sutton system of biological purification. The sewage is first strained of large particles by means of fine metal strainers introduced at the sewer outfall, where the sewage enters the works; it is then exposed to downward filtration through coarse beds. It is in these coarse beds that liquefaction should take place. They are 4 feet deep, and made of coarse burnt ballast of particles of such a size that they will pass through a 2-inch ring, but are rejected by a ½-inch mesh; the object of using such coarse material being to admit the solid particles of crude sewage into the body of the bed, and also to favour thorough aeration when the liquid sewage is drawn off. The coarse material, moreover, does not get so readily clogged. The effluent from the coarse bed is then conveyed on to the surface of a fine filter, 4 feet deep, constructed of particles which will pass a ¼-inch mesh, but which are rejected by one of $\frac{1}{16}$ inch.

The sewage is allowed to fill these beds almost to their top surfaces, and then to rest in them for a period of two hours (hence they are known as *contact-beds*). Then the beds are slowly emptied and allowed to remain at rest for several hours, so that several of such filters are necessary in even a small installation. Each filter-bed is filled up thrice daily. This intermittent application of the sewage insures also a certain amount of aeration of the beds. One drawback to the use of the coarse or " roughing " filter is the fact that the upper stratum of the filtering material becomes clogged at intervals with a black deposit of solid matter. The surface of such filters, therefore, requires occasional raking or ploughing.

The practice of applying the crude sewage by a single carrier to a coarse continuous bed would have the effect of overtaxing the bed on either side of the trough, for the material there will collect more than its share of suspended matter whilst the bed is filling; such a filter, therefore, is not given the best chance of carrying on its work.

Kenwood and Butler found that in installations upon Dibdin's principle with coarse and fine contact-beds, a greater area of coarse filter than of fine filter should be provided, and that the sewage should be locked up for longer periods (4 hours) in the coarse beds, and shorter periods (2 hours) in the fine beds. It is in the coarse beds that the liquefaction of the solid matter takes place, and the stability of the organic matter in solution is shaken, and time is the all-important element in bringing about these changes. Their experiments also demonstrated the fact that, for the second stage of purification, the transference of the sewage from one bed to another in a series of two or three beds brought about a higher degree of purification in a shorter time than prolonged treatment in one bed alone; for a filter will effect only a certain percentage reduction of the polluting ingredients of the sewage it receives, even when it has reached its maximum biological efficiency.

The point always to be borne in mind is that what has to take place is not merely the reduction of unstable matter to ultimate products, but the reduction of the more stable organic matter to the unstable. The reduction of the unstable to the ultimate appears to be best effected by change of filters, that of stable to unstable by rest in a filter.

Contact-beds of coarse coke-breeze or burnt ballast, used to

receive crude sewage, separate a large proportion of the suspended matter of the sewage; hence their capacity for liquid generally settles down to a smaller proportion, represented commonly by an average figure of 25 per cent. The eight hours' cycle of treatment of these filter-beds meets with the approval of the Local Government Board, the time being allotted as follows: 1 hour to fill, 2 hours to rest full, 1 hour to empty, and 4 hours to rest empty. It has now been proved that such contact-beds can be worked at the rate of 1,000,000 gallons per acre per diem, if the eight hours' cycle is strictly maintained.

Septic Tank.—The "septic tank" method was devised by Mr. Cameron of Exeter at about the same time that Mr. Dibdin's experiments were in progress.

The method, like that of Mr. Scott-Moncrieff, provides for a well-defined line of demarcation between the stages of liquefaction and of subsequent purification. Provision is made for liquefaction under strictly anaerobic conditions in a large covered receptacle provided with an inlet for the sewage and an outlet for the tank effluent. The sewage travels so slowly through the tank that every particle takes some twenty-four hours in passing through it. This period of time is sufficient for such a complete sedimentation and liquefaction of solids to be effected that the tank effluent should contain but a few grains per gallon of fine suspended matter. The black deposit which settles in the bottom of the tank was found after fifteen months' working to be under 2 feet in depth. This deposit consists of indigestible material, and includes mineral matter, cellulose, vegetable and elastic fibres, cartilage cells, etc. The gases given off from the tanks are not offensive, but are highly inflammable. The mixture of gases contains (Rideal) $CO_2 = 0{\cdot}6$, methane $= 24{\cdot}4$, hydrogen $= 36{\cdot}4$, nitrogen $= 38{\cdot}6$, in 100 parts.

The second stage of purification is effected by passing the dark-coloured tank effluent through an "aerator"—a long trough over the edges of which the liquid falls in thin films, thereby mechanically entangling a certain quantity of air, and from thence on to a series of coke-breeze filters $4\frac{1}{2}$ feet deep. These filters are filled, rested while full, slowly emptied, and rested for several hours while empty, in the manner advocated by Mr. Dibdin. The effluent from the tank is applied to the filters in rotation by an ingenious automatic arrangement, which removes the necessity for continuous manual attention. The

practice at Exeter leads to about six hours being consumed in the filling of each filter, which then remains full for six hours; the filter is then emptied in half an hour, and is allowed to remain at rest for the remainder of the twenty-four hours (*i.e.*, eleven and a half hours).

When sewage is allowed to flow slowly through an open tank, a thick spongy scum gradually covers the surface. The effluents furnished by similar sewage from an open "scum" tank and a closed septic tank are very similar to each other. The scum provides a cheap roof which preserves the heat in the sewage, and thereby promotes bacterial action, and also tends to prevent the dissemination of smell from the tanks. One may broadly summarize the advantages of anaerobic tanks as follows: They promote uniformity of effluent; they permit of the digestion of from 30 to 40 per cent. of the suspended solids of sewage, with the result that such solids in the tank effluent rarely exceed 15 to 20 parts per 100,000; the stability of most of the organic solids is rapidly reduced by a short sojourn in a tank, and subsequent purification thereby much facilitated.

Slate-Beds.—The difficulties often arising from the treatment of the highly offensive effluent from a septic tank led Dibdin to advocate the preliminary treatment of crude sewage in *slate-beds*, in which it is only retained for two hours, so that it emerges in a fresh condition. The slates, which are the refuse of slate quarries, are laid horizontally in layers about 2½ inches apart, in a bed about 4 feet deep. The slates are supported on small slate slabs of the required thickness. These beds are filled from the top, and emptied from the bottom, the sewage remaining at rest for two hours, and the beds being left empty for a like period. This process is now at work at Devizes, where the crude sewage is very strong, and is mixed with the refuse from breweries. The effluent from the slate-beds is clear and inodorous, and is in a condition very suitable for application to the contact-beds of fine clinker, in which the process of purification is completed. A certain amount of silt from the sewage is deposited on the slates, but the amount so collected is not large, and it has not been found necessary to wash out the silt more frequently than once or twice a year. The deposited silt soon loses any sewage odour, and has the character of rich mould when taken from the slates, with a strong earthy smell.

Slate-bed installations have been successfully adopted in

many places of recent years, and have been found to give satisfactory results. Where the sewage is abnormally strong, and the fæcal matter has had no time to disintegrate, as in barrack sewage, and especially in barracks where there is much stable drainage, the quantity of suspended matter is often so great as to choke the lower portion of the slate-beds, with the result that putrefaction occurs, and the last portion of the slate-bed effluent is highly offensive. In such installations the crude sewage should be sedimented in detritus tanks before passing to the slate-beds; and, if the slate-bed effluent contains much suspended matter, it should be made to flow through a shallow "humus" bed to deposit the fine sediment before it is distributed to contact-beds or aerating filters. In this way the tendency of secondary filter-beds to become clogged with humus from a slate-bed effluent may be counteracted. The great advantage of the slate-beds in a satisfactory installation is that the primary effluent is inoffensive, and much less liable to create a nuisance on secondary treatment than is the septic effluent from a septic tank.

Dr. Travis's "hydrolytic" tank is based on the principle that when suspended solids reach so fine a subdivision as to become colloidal, they present so small a ratio of bulk to surface that they have little tendency to gravitate, and are dispersed by the least eddy. This tank provides for their aggregation into masses of greater size—and hence of greater relative weight—by multiple surfaces afforded by slatted wooden frames in the last chambers of a series through which sewage slowly passes, the aggregated particles falling into sludge channels and sliding to a central sump.

In the "*activated sludge*" method of sewage treatment, compressed air in a finely-divided condition is forced through the sewage in an aerating tank for a period of four hours in the proportion of 1·75 cubic feet of air per gallon of sewage. After aeration the sewage is passed into a settling or sludge tank, where the sewage is at rest, and deposits the sludge. The effluent water above the sludge in this tank is fairly clear and non-putrescible, and may be discharged into a stream of sufficient volume and flow. The sludge in the settling tank is then forced back by compressed air into the aerating tank, to be mixed with fresh inflowing sewage, and again subjected to aeration. Any excess sludge is removed from the settling tank, and dried by exposure to air, before being disposed of. In this process of

aeration of sewage and sludge the aerobic bacteria are much increased in numbers and activity, causing oxidation of dissolved and suspended organic matters, and stable non-putrescible effluents and sludge are produced, if the system is worked with care, and the effluent and sludge are fully matured. Carbon is rapidly oxidized to CO_2, while the nitrogen is so fully fixed by nitrification that the sludge contains some 6 per cent. of nitrogen, and is therefore more valuable as a manure than the sludge resulting from other methods of sewage treatment. No filter-beds are required in this process, and only a small area of land is necessary.

Installations of the "septic tank" or slate-beds must be sufficient to hold at least twenty-four hours' dry weather flow of sewage. The matter is, however, complicated by the necessity of making provision for some at least of the storm water, which may at times swell the dry weather flow, for during rainy periods the volume of sewage is often more than quadrupled. The Local Government Board requires that storm water amounting to thrice the dry weather flow of sewage must be treated in every respect as the sewage, while any additional quantity of storm water up to six times the dry weather flow must receive special treatment, either by means of an artificial filter or by land used for no other purpose. The storm water over and above six times the dry weather flow may be discharged into a stream. Local authorities must therefore make provision for the treatment of six times the dry weather flow. Special storm water filters of burnt ballast, etc., will deal satisfactorily with 500 gallons of dilute sewage to each superficial yard of filter area (2,420,000 gallons per acre) per diem.

Aerating Beds and Streaming Filters.—*Aerating filter-beds* must be constructed of fine grain material. The nature of this material, given that it is hard and durable, does not appear to be a matter of prime importance. It may be of coal, cinders, coke, clinker, saggars (refuse pottery), burnt ballast, gravel, or flint, and local circumstances may be left to determine which to select. Coke is generally scarce and expensive, coal is expensive, and, like burnt ballast, gravel, and flint, can often only be obtained by the payment of heavy charges for carriage. Sand and gravel do not appear to be so satisfactory as filters of clinker, coke, coal, and burnt ballast. In order to secure good and uniform results, the filters should never be made to deal with more than

a million gallons of average sewage per acre per diem (about 200 gallons per superficial yard). The water capacity of these fine grain beds diminishes somewhat with use owing to the retention of solid sediment, until as a rule a stage of equilibrium is reached, when the liquid capacity of the bed generally averages about 33 per cent. of the total cubic capacity.

In Toronto streaming or trickling filters have been made of brushwood, and found to answer well, being capable of treating sedimented sewage at the rate of 6 million gallons per acre per day. The brushwood is pressed into bundles and bound by wire, the bundles being placed together to form a filter 4 feet deep. A space is left in the centre to allow air to enter freely from the centre, as well as from the sides. The sewage is distributed over the filter by a revolving sprinkler. In a few weeks the filter is mature, the brushwood being covered with a slime containing nitrifying bacteria and protozoa. A high degree of nitrification of the sewage is then obtained, and the effluent is uniformly stable. It is found that the filter-bed so constructed is of a lasting nature, as the wood, being constantly wet with trickling sewage, shows little tendency to decay. In rural districts brushwood is easily and cheaply obtained, and skilled labour is not required in the construction of the filter.

If the aeration beds (commonly known as *streaming* filters) are treated intermittently (and excellent results can be got by this method), then the sewage must be applied evenly and equally over the whole area of the filter. It is difficult to effect this with ordinary fixed trough distributors; but it can be provided for by means of revolving sprinkling arms, such as Candy's, or the Fiddian Rotary Distributor, which automatically revolve horizontally over a circular bed, the motive power being loss of head (about 1 foot) by the passage of the sewage on its way to the sprinkling arms. Stoddart's distributor consists of a galvanized iron channel furrowed with numerous narrow gutters in close parallel rows. Along the under surface of each gutter is a series of small perforations terminating in vertical points. The clarified sewage, entering these gutters (preferably through "tippers" which automatically fill and discharge), forms drops upon each of the vertical points which drip steadily on to the filter-bed immediately below. Streaming filters are more expensive to construct and maintain than contact-beds, and are more often a nuisance from flies. The chief source of the white-

winged fly, so common on many coarse percolating filters, is the accumulation of undigested suspended and colloidal matter with gelatinous growths, which occur immediately below the surface of percolating or streaming filters.

The methods of distribution of tank effluent over filter-beds by means of elongated water-wheels, which, pivoted at the centre, roll bodily over the surface of a filter on circular rail-tracks laid around the circumference of the filter, or by travelling distributors, in which the water-wheels pass backwards and forwards over rectangular beds, are far preferable, from the point of view both of even and regular distribution of the effluent over the filter and also of lessened likelihood of nuisance, compared to the revolving sprinklers and fixed nozzle distributors. In the water-wheel distributor, the effluent falls in thin sheets, and has but little depth of air to traverse, the water-wheel being close down upon the bed, unlike the fountain sprays of the sprinkler and nozzle distributors. Consequently there is less risk of effluvia being conveyed by winds to considerable distances.

A bacterial filter of coke will cost from £2,000 to £4,000 per acre, and each acre will treat from 500,000 to 1,000,000 gallons daily, according to the nature of the sewage.

The amount of purification exerted by a filter or installation may be expressed as a percentage calculated upon the reduction in the albuminoid ammonia and oxygen absorbed figures of the liquids before and after treatment. In many installations such purification amounts to over 80 per cent. of the original pollution.

It is an interesting matter to note that the total nitrogen in organic combination in the sewage which enters any of these installations is not nearly accounted for in the NH_3, nitrates, nitrites, and the organic nitrogen still remaining in the final effluent. The loss is doubtless due to the fact that free nitrogen passes away from the beds, possibly also oxides of nitrogen, and a considerable amount of ammonia.

The artificial warming of bacterial beds, though it increases bacterial activity, is not necessary; for even in the coldest winter months the temperature of the body of the beds rarely falls below 50° F., though the temperature of the atmosphere may be below 40° F.

It may be taken for granted that circumstances favouring high oxygenation promote the ultimate changes of purification and the production of an effluent with good physical characters

—incapable of putrefaction and of developing odour. Efficient oxygenation is aimed at in the system of emptying and filling fine bacterial beds in Dibdin's method, in the aerating channels and beds of the "septic tank" method, in the nitrifying channels and trays of Scott-Moncrieff, in the Ducat filter, Stoddart's distributor, Lowcock's filter, Adeney and Parry's suggestions for the addition of small quantities of an oxidizing agent in the effluent, and in the use of sprinklers and water-wheel distributors over streaming filters. Contact-beds do not secure oxygenation of the effluent so well as some of the other methods in practice; and observations go to show that the best results are to be obtained by an intermittent application of the previously sedimented sewage upon a raised bed, which is unenclosed, or the outlet pipe of which, when enclosed by a retaining wall, is constantly open (streaming filters).

With the evidence at present available, it is extremely difficult to decide as to the respective merits of all of the installations which have been advocated. Sewage varies so much in its characters, and in the relative proportions of its different constituents, that experiments performed on different sewages afford no precise information on which can be based a safe and scientific comparison.

Any opinion expressed must, therefore, be accepted with reservation, but probably every one of the methods referred to may be made to give satisfactory results. Questions of economy of plant and of time, of working and maintenance, and of the relative applicability of the process to local wants and conditions, must and will ultimately determine the choice.

Trade Effluents.—When certain trade effluents, especially waste acids, are passed into town sewage, experiment alone can decide whether it will be necessary to employ a preliminary chemical (lime) treatment prior to bacterial treatment in filter-beds. It is certain that the natural agencies of purification are for the most part capable of dealing with such quantities of the trade effluents as more usually find their way into sewage. It would, however, be advantageous if manufacturers could be made to distribute the discharge of trade wastes more equally over the twenty-four hours; and in some cases the waste products should undergo some purification or treatment before they are permitted to leave the premises on which they are produced.

Trade effluents may be objectionable by reason of the presence

of excessive amounts of suspended matter, such as lime, clay, shale, fibre, fine stone, or coal, etc. In most cases the suspended matter may be removed by simple subsidence in suitably constructed settling tanks, aided, if necessary, by the addition of such chemicals as lime, copperas, or alumino-ferric. Fine screens or specially adapted straining filters may be necessary in some cases.

The introduction of brewery, tannery, glue-factory, etc., waste into sewage is often productive of nuisance in the subsequent processes of treatment, more especially in the case of small towns, where the brewery waste forms a considerable proportion of the total volume of liquid carried to the outfall sewer. The brewery waste has an aromatic odour, which is penetrating and disagreeable, and is sometimes perceptible at a considerable distance from the sewage works. In such cases it may be desirable to have the septic tanks covered over, and not to employ sprinklers to distribute the tank effluent over the streaming or aerating filters, as the wind passing through the effluent issuing from the sprinklers may convey smell to a distance. If the sewage works are in the neighbourhood of dwellings, primary and secondary contact-beds are less likely to be productive of nuisance than sprinkler-beds; and if streaming filters are to be used, fixed distributors will be preferable to revolving sprinkling arms. But it is generally preferable to obtain some treatment of such trade effluents before they are admitted to the public sewer. They may be purified, with or without preliminary dilution, by lime; and, after precipitation, they may be passed through filter-beds or applied to land.

Sewage rich in fatty and soapy matters, as in districts where certain manufactories and laundries are numerous, is very retractable to purification by biological agencies. The fat is especially resistant, and tends to coat the particles of which the aerating beds are composed, thereby reducing their biological efficiency, and presenting obstacles to the passage of the sewage through a fine filter. Trade effluents containing much fat should be treated before being passed into the public sewers. The fat may be largely removed by suitably constructed grease-traps, or recovered by treatment with acid or, in the case of soap, with lime.

In the Ninth Report (1915) of the Royal Commission on Sewage Disposal, it is recommended that there should be standards, which should be capable of some variation, for the different kinds of trade effluents, and that the existing legal powers with regard to trade pollution should be amended.

The Purity of Effluents.—There is no evidence of the elimination of the micro-organisms characteristic of sewage by any process of filtration in bacterial filter-beds. It is evident, then, that such processes can in no sense be regarded as effectual in preventing danger, where filter effluents are discharged into streams used for water supply, into water where water-cress is grown, or into estuaries where oysters are laid.

The Royal Commission on Sewage Disposal appointed in 1898 reported at the end of 1903 that they were satisfied that the consumption of shell-fish specifically polluted by sewage may cause enteric fever and other illnesses, and that bacteriology at present cannot be relied upon to determine whether or not shell-fish are so polluted. It is, however, a fact that a very much smaller number of *Bacilli coli* or coli-like microbes are found in oysters stored in pure water than in those stored in polluted waters. In the opinion of the Royal Commission tidal waters should be placed under the jurisdiction of some competent authority, whose duty it would be to see that where shell-fish are collected, fattened, or stored, there is no risk of dangerous contamination. They further recommend that in respect of imported shell-fish similar precautions should be demanded as a condition of their importation to this country; and, in default, all imported shell-fish should be deposited in registered layings for at least six weeks antecedent to their disposal on the market.

The same Royal Commission reported in 1901, that while in the case of sewage effluents from land which is of a kind suitable for the purification of sewage, there are fewer micro-organisms of intestinal origin than in the effluents from most artificial processes, yet any sewage effluent must be regarded as potentially dangerous. In conclusion they say that the general protection of our rivers is a matter of such grave concern as to demand the creation of a separate Commission, or a new department of the Local Government Board, which shall be a Supreme Rivers Authority, dealing with matters relating to rivers and their purification, and which, when appeal is made to them, shall have power to take action in cases where the Local Authorities have failed to do so.

A satisfactory sewage effluent must be without fæcal odour and marked deposit. In the opinion of many, the organic ammonia figure is the best criterion of a satisfactory effluent. It is held by some authorities that this figure should not exceed 0·1 part

per 100,000, while others advocate a limit of 0·15, or even 0·2. The oxygen absorbed by oxidizable organic matter in four hours at 80° F. does not exceed 1·5 parts per 100,000 in good effluents. The chlorine and free and saline ammonia figures are unimportant, since these are ultimate products; the chlorine in the effluent of a sewage of average strength is about 10 parts per 100,000. There should be practically no solids in suspension; the Rivers Pollution Commissioners' standard required that the suspended matter should not exceed 3 parts of dry mineral matter per 100,000, nor 1 part of dry organic matter per 100,000. Above all, the final effluent must not be liable to putrefaction or secondary decomposition.

The presence of oxidized nitrogen in an effluent must not be regarded as a sure index of purity, although if nitrates are found to persist in an inoffensive effluent for a few days after its collection, the effluent is not likely to become offensive. Nitrates are a measure not of that pollution which may be oxidized, but of that which has been oxidized, and their presence gives no indication of what remains to be purified.

No general standard applicable to all cases is possible or desirable. The best possible results must always be aimed at, having due regard to the nature of the sewage, and to the conditions, volume, and uses of the stream which is ultimately to receive it. The maximum impurity permissible will in certain cases be very slight indeed, while in others a greater latitude may be conceded. But certainly all effluents should conform to the following requirements: they should contain but very little suspended matter (certainly not more than 3 parts per 100,000); they should possess no odour of sulphuretted hydrogen; and there should be no physical evidence of putrefaction when they are incubated for a week in a closed vessel at 80° F.

The Eighth Report of the Royal Commission on Sewage Disposal (1912) suggests, as the most generally satisfactory test for a sewage effluent, discharged into non-tidal waters, the determination of its capacity to absorb dissolved oxygen, the test to be applied to the effluent with all its suspended solids, and not to the filtered effluent as recommended in the Fifth Report of the Commission. The absorption of dissolved oxygen should be allowed to proceed for five days at a uniform temperature of 65° F., and in this period the absorption of dissolved oxygen should not exceed 2 parts by weight per 100,000 parts

of effluent (=14 c.c. per litre). Further, the effluent should not contain more than 3 parts of suspended solids per 100,000.

The average amount of oxygen found in clean fresh water saturated with this gas is 1 part per 100,000, or 7 c.c. per litre. The Commissioners consider that if a river water, which has received sewage effluent, does not take up more than 0·4 part of oxygen per 100,000 in five days at 65° F., the water will be ordinarily free from signs of pollution; but if the absorbed dissolved oxygen is above this figure, signs of pollution will almost certainly be apparent, with a strong probability of nuisance arising.

The effect of an effluent upon a stream does not generally depend upon the absolute amount of organic matter contained in it, but rather on the nature and condition of the organic matter. The important point to ascertain in examining an effluent is the extent to which the original organic matter has undergone fermentation. Thus, an effluent which is non-putrescible on incubation must already have undergone a satisfactory amount of fermentation. Not only will it remain stable when discharged into a stream, but it will also take up but little dissolved oxygen from the water into which it is discharged. An effluent which does not take up dissolved oxygen from the water of a stream more rapidly than that water can naturally re-aerate itself from the air, will be unproductive of nuisance, and will not injure fish life.

As regards solid suspended matters in effluents from artificial filtration processes, on an average two-thirds of them are volatile, *i.e.*, organic, and one-third are mineral. The organic solids are practically always putrescible, and capable of taking up oxygen from water comparatively rapidly. So long as such solids are kept moving in oxygenated water, or in water containing nitrate in solution, they will cause no nuisance; but if allowed to accumulate in the sluggish reaches of a stream, they will ultimately form a black and putrid mud.

Nuisance may not only be caused in a stream by secondary fermentation of the organic matters in a sewage effluent, but the effluent may cause the growth in the stream of lowly vegetable organisms, which often give rise to nuisance and difficulty. Even the best effluents contain a certain amount of plant food in solution, and therefore tend to promote vegetable growths. In the case of a stream receiving well-purified and nitrated

effluents these growths are green, from the presence of chlorophyll, and are unproductive of nuisance until they become detached and decompose. In streams receiving imperfectly oxidized effluents, containing much sulphates, grey growths of the sewage-fungus order arise, and tend to choke up the bed of the stream, at the same time causing an offensive nuisance when decomposition occurs.

Effluents conforming to a satisfactory standard may cause considerable growths of organic life, which may subsequently produce a nuisance. There is much to learn of the causation of these objectionable growths, but certain of them are doubtless promoted by the presence of nitrates. *Carchesium* (constituting whitish masses of filamentous growth, characterized by bell-shaped heads on thread-like stems), green growths of *Oscillatoria nigra* and *Spirogyra*, and coarser growths of water-weeds may grow in well-purified effluents; and imperfectly purified effluents may foster such grey growths as *Leptomitus* and *Sphærotilus*, or even *Beggiatoa*.

A large thin-leaf seaweed, of cabbage-green colour and known as sea-lettuce (*Ulva latissima*), like different species of the grass-like *Enteromorpha*, etc., flourishes in association with the sewage pollution of sea-water. The ulva grows most extensively in those estuaries where the water is shallow and the tidal movements are slow and ineffectual in carrying all the sewage pollution out to sea at each ebb of the tide. We are indebted to Professor E. H. Letts for much information with reference to this sewage seaweed. He finds that it absorbs nitrogen from the ammonia and nitrates of sewage origin, and that mussels attach themselves to it by their byssus threads. After the ulva reaches a certain size, wave action detaches most of it, and the small retained pieces are capable of continuing the growth of the plant. If the detached ulva is not swept out to sea, it accumulates on the shore, where, exposed to the sun and air, fermentative decomposition sets in, and a micro-organism reduces the sulphates (which are abundantly present in the tissues of the ulva) to sulphides; and eventually sulphuretted hydrogen is liberated and an intolerable nuisance results.

The weed is also found in some places where the sea-water is free from sewage pollution, in sheltered and shallow waters with sluggish currents, and where the means for its anchorage exist.

Intermittent Downward Filtration.

When sewage percolates through porous soil, it is purified to a greater or less extent. This purification is partly due to the soil acting as a mechanical filter, separating out and retaining the suspended matters in the sewage, but greatly more to the destruction by organisms of the organic matters in the sewage. This purification is chiefly effected by the bacterial organisms which exist in the upper layers (extending to 3 or 4 feet from the surface) of all soils, but chiefly in those rich loamy soils which contain much organic matter. The nitrifying organisms feed on the organic matters of sewage, causing their oxidation. They require air and oxygen for their growth and life, which are supplied to them when the soil is being aerated during its periods of rest. The soil or the sewage should also be rich in lime or other alkali; for the nitric and nitrous acids formed by the nitrifying organisms must be able to combine with bases, or the nitrifying action ceases.

A very large volume of sewage can be purified on a small area of land if the soil is of a porous and rich loamy character. Sandy soils are not efficient purifiers—at any rate at first. Clay, and other retentive soils, must be well broken up and mixed with ashes. The surface of the land must be levelled, and under-drained with porous tile drains, laid at a distance of about 10 to 30 feet apart, according to the nature of the soil, and at a depth of 4 or 5 feet from the surface. The area should be laid out in plots; and no plot should receive sewage for more than six hours, so that it may have eighteen hours' rest out of the twenty-four; to this end the screened, filtered, or precipitated sewage is distributed over each plot of ground intermittently by means of branching carriers. If it is intended to apply the sewage of more than 1,000 people to an acre, the sewage should be treated chemically, or passed through a septic tank, to remove the suspended matters, and the clarified sewage only should be applied to the land.

When the crude sewage is applied in large volumes to a small area of land, the pores of the soil become clogged with the slimy suspended matters, and a kind of coating is formed over the surface, which prevents the percolation of the sewage and the penetration of air into the interstices of the soil. When the sewage of considerably less than 1,000 people is to be applied

per acre, the screened sewage may be applied in its crude state; for it is much cheaper to allow the suspended matters to reach the soil by gravitation in the liquid sewage than to separate them by precipitation and then, as is sometimes necessary, to pump the liquid sludge on to the land. It is generally the practice to lay out the filter areas in ridges and furrows, the sewage being allowed to flow down the furrows, whilst vegetables are grown on the ridges. The roots of the vegetables assimilate organic products, and thus help to purify the sewage, whilst the leaves and stalks, being above the sewage, are not contaminated by floating matters. The suspended matters deposited from the crude sewage in the furrows must be dug into the soil from time to time, before they have time to form an impenetrable coating.

By intermittent downward infiltration through specially prepared filter-beds, the clarified sewage of even 5,000 people can be applied to each acre of filter; but it is not really safe to allow less than 1 acre to each 1,000 of population (20,000 to 30,000 gallons daily of dry weather sewage flow) when the intermittent downward filtration is through soil, however suitable the soil may be. Under favourable circumstances, the effluent water issuing from the drains will be found very free from organic matter. The nitrogen of the sewage exists in the effluent water, but in the innocuous forms of ammonia, nitrates, and nitrites. The sewage, therefore, by this process is effectually purified; but all its manurial ingredients are wasted, except in those cases where the sale of vegetables, grown on ridges, covers part of the cost of the distribution. But the area of land being so limited, the crops, and the income derived from their sale, must necessarily be very small.

Irrigation.

In the words of the Royal Commission on Metropolitan Sewage Discharge, broad irrigation means "the distribution of sewage over a large surface of ordinary agricultural ground, having in view a maximum growth of vegetation (consistently with due purification) for the amount of sewage supplied." Filtration means "the concentration of sewage at short intervals, on an area of specially chosen porous ground, as *small* as will absorb and cleanse it; not excluding vegetation, but making the produce of secondary importance. The intermittency of application is a

sine qua non even in suitably constituted soils, wherever complete success is aimed at."

It becomes necessary to inquire what are the conditions under which the crude sewage of a town may be applied to land by broad irrigation. Experience has taught that no great profit should be looked for from a sewage farm. Unfortunately local authorities have found great difficulty in acquiring sufficient land at a low rental for purifying sewage.

In the first place, the land chosen should be so situated in relation to the town that the sewage may flow to it by gravitation; pumping is costly and greatly reduces any profits that may arise. The rent to be given for the land ought not to exceed £2 10s. per acre (Bailey Denton). The extent of land that should be acquired varies under different circumstances; on an average 1 acre to every 100 to 200 persons of the population is sufficient. The best kind of soil is a friable loam; but clayey, gravelly, or sandy soils are all capable of purifying and utilizing sewage when properly managed. "Peat and stiff clay soils are generally unsuitable for the purification of sewage" (Interim Report of the Royal Commission on Sewage Disposal, 1901). The land must be levelled, and, unless very porous, underdrained, to allow the sewage to percolate and prevent its stagnation on the surface. With very dense clay soils filtration is impossible, and in such cases surface flow must be entirely relied upon. This is capable of giving a fairly pure effluent if the sewage has been freed of suspended matters by a preliminary precipitation, and if the area of the land is sufficient. In these cases underdrainage should not be attempted, as in dry summer weather the stiff clay soil cracks, and the sewage may pass away directly through the fissures into the underdrains, and so reach the watercourses unpurified. The main carriers for the distribution of the sewage on the farm should be masonry, concrete, or stoneware channels, which can be easily flushed and cleansed.

Great care must be exercised where sewage is allowed to irrigate land of a chalky nature, or where a top layer of clayey soil of but little thickness covers a thick stratum of chalk. In certain chalk formations, what are known as "swallow holes" exist —that is, extensive fissures in the chalk reaching up to the surface. In such cases it sometimes may happen that unpurified sewage flowing over the surface may disappear into one of these fissures or swallow holes and pollute the underground water,

which at no great distance away may be pumped out of a deep well in the chalk to supply houses, villages, or towns. Such an occurrence is believed to have occurred at the East Riding Lunatic Asylum, near Beverley, Yorkshire. The top layer of clay became extensively cracked in dry summer weather, permitting unpurified sewage to pass through to the chalk beneath, where it was conducted by fissures to the deep well, about half a mile distant, which supplied Beverley with water. As the water in this well was sometimes depressed by pumping to the extent of 17 feet, the area of the circle drained by the well must be very extensive. In the immediate neighbourhood, a stream much polluted by the sewage of a village on its banks disappeared into one of these swallow holes, where the chalk rises up into the bed of the stream.

The method most capable of general application for applying the sewage from the main carriers to the surface of the farm is that known as the *ridge and furrow* system. The surface is laid out in ridges—30 to 60 feet broad—running parallel to each other, and at right angles to the main carrier, with a slight fall from it. Between every two ridges is a furrow formed by the slope (a fall of several inches) of the two ridges towards each other. The sewage is made to pass down a grip in the centre of the ridge, and thence to flow over the sides towards the furrow. When the central grip becomes clogged with the suspended matters of the sewage, it should be filled in, and a fresh one made in its place. The underdrains of porous earthenware should be laid at a depth of about 5 feet in the soil, and from 20 to 100 feet apart, according to the porosity of the soil.

What is known as the "catch water system" of irrigation can be adopted where the areas for sewage treatment have sufficient gradients. By this method a series of furrows or trenches are dug in lines one below the other. The sewage is conducted to the topmost trench, over which it passes to find its way into the next lower trench, and so downwards to the bottom of the slope, where the subsoil effluent is collected and carried into a stream.

The best crops for a sewage farm are Italian rye grass, roots (mangold wurzel), and cabbages. Italian rye grass absorbs a large volume of sewage, and bears from five to as many as seven cuttings in the year. After two or three years, the plot of rye grass should be ploughed up, and the land sown with

cabbages or roots (mangolds). These may be sewaged when growing, but they should not be sewaged when they arrive at maturity. They help to exhaust the soil of the sewage products retained in it, which have not been absorbed by the rye grass. Pulse, cereals, and all other vegetables should not be sewaged when in growth, except in times of great drought. The land, when fallow, may be enriched by the application of sewage; for some of the manurial ingredients of sewage are doubtless retained in it, ready for use on a future occasion. Market gardening may be undertaken, and made very profitable on farms where the area of land is more than sufficient to deal with all the sewage; but, where this is not the case, market gardening does not answer, because the area so cultivated cannot deal with the whole volume of sewage.

The amount of capital required to stock and work a sewage farm is very great, probably five times the amount required for an ordinary farm. The crops that have to be taken off the land are enormous, and a large amount of labour is required to keep it clean and free from weeds. The crops of Italian rye grass, being so large, may—and often do—exceed the demands of the local markets. If not sold at once, the grass is wasted; for it will not keep, and will not bear long carriage. In dry summers it may be made into hay, and at other times it may be converted into ensilage. It has been found, however, that, to reap the greatest profits from a sewage farm, the produce should be converted into milk and meat. In other words, a dairy farm should be established, and stock should be reared and fattened for market. The idea that sewage-grown vegetable produce is dropsical and prone to decompose has been long exploded. The milk and meat, also, from animals fed on such produce in no way differs from milk and meat produced on ordinary farms.

From experiments extended over five years (1871-76), the British Association Sewage Committee found that the average amount of nitrogen recovered in the crops of a sewage farm was 32·88 per cent. of that applied in the sewage. About 11 per cent. of the nitrogen in the sewage escapes in the effluent water, almost entirely as nitrates and nitrites, whilst a portion of the unaccounted-for nitrogen is stored up in, and enriches, the soil of the farm.

The amount of evaporation of water from the surface of a sewage farm is enormous. The above committee found that,

on an average of over a year's observations, only 47·3 per cent. of the sewage pumped on to the land was discharged through the deep drains as effluent water. This fact must be reckoned with on making analyses of effluent water from sewage farms, which are to be compared with samples of crude sewage flowing on to the farm. Although the evaporation of water is so great, the committee found that there was no loss of ammonia from the sewage by evaporation in its passage along the open grips and carriers on the farm.

One of the great drawbacks to the utilization of sewage by irrigation is the fact that the sewage must be applied to the land as it comes, by night as well as by day; on Sundays as well as on weekdays. There may be times when it may not be desirable to apply sewage to the general surface of the farm, especially during wet weather, when enormous volumes of dilute sewage arrive at the farm. This difficulty may be got over by laying out a portion of the farm as a filter-bed closely drained. The extent of this filtration area should be sufficient to purify the whole of the sewage when not required on the general surface of the farm. The land may be left fallow, or laid out in ridges and furrows and cropped. When the sewage is much diluted with storm water, it may, in other cases, be carried over a specially prepared filtering area planted with osier beds, or over meadow lands, before being discharged into a stream. It would be of great advantage if storm and subsoil waters could always be excluded from the sewers; the problem of satisfactory disposal of the sewage would be thereby greatly facilitated.

During the most severe frosts irrigation may continue uninterruptedly. A coating of ice is formed over the surface of the farm, but the sewage, which always has a temperature well above the freezing-point, flows underneath this coating and sinks into the soil, which remains unfrozen and open. As the weather moderates, the sewage rapidly melts the ice above it. Even in America, where the frosts are most intense, no trouble has arisen from this cause on any of the sewage farms.

Are sewage farms productive of nuisance and injury to health ? There can be no doubt that badly managed farms—where more sewage is applied than the land can absorb and cleanse, or where, from the sewage being applied too continuously, the surface becomes sodden, and ponded sewage stagnates on it—may be a nuisance. When properly conducted, and the sewage is

distributed over the land in as fresh a state as possible, and not after prolonged sojourn in a lengthy main or outfall sewer, sewage irrigation is not found to be productive of any nuisance.

That sewage farming is no more unhealthy than ordinary farming is shown from the returns of the nine sewage farms which were in competition for the Royal Agricultural Society's prizes. The rate of mortality amongst the labourers and their families, on an average of the number of years these farms had been in operation, did not exceed 3 per 1,000 per annum. No facts, either, have ever been brought forward in favour of the view that entozoic diseases are spread by the agency of sewage farms. It is probable that alkaline sewage destroys organisms like the ova of tapeworms, whose natural habitat is the acid secretion of the human intestines. If so, they are destroyed before they arrive at the farm. On one farm, too, it was found that there was a remarkable absence of those molluscan and insect forms of life which frequently play the part of intermediary bearers to entozoal larvæ, and without which the cycle of their existence cannot be completed. Even where cattle have been allowed to feed upon land to which sewage is being applied, it has not been found that they are in any way affected with parasitic diseases.

Generally speaking, land is becoming too valuable to be put to purposes of sewage purification, hence the modern endeavour to reproduce all the most favourable conditions of land and to concentrate them in a small area known as a bacterial bed; but where land, suitable in nature and quantity, can be procured, equally good results are obtainable.

Note on Camp Sanitation.

Where trenches are provided for excrement, these are kept quite shallow (12 to 18 inches deep), and not much over a foot in breadth. These are dug on a carefully selected site to leeward of cook-houses, canteens, and tents, and at least a hundred yards distant from these. The grass sods and the earth removed are placed near to the trenches, but not close enough to get contaminated. The number of trenches dug is the number that will require filling in daily, so that the good practice of fresh trenches every twenty-four hours is followed wherever the area of ground available renders this possible. But it would give

rise to offensive odours, and during the summer and fly season it would not be safe, if this excremental matter were left exposed in the trenches for many hours; and so camp sanitation demands that when a soldier uses such a trench he shall place some earth over his excrement. Some of the small mound of earth at the head of each trench may be applied by means of a small shovel or empty tin, and this wise precaution can be carried out in a moment or two. Of course, if chloride of lime or other disinfectant is provided, that is applied. When the refuse matter reaches to within 6 inches of the surface, clean earth is applied, and this is tightly packed to a depth of at least 6 inches, or 9 inches in the fly season; this guards against nuisance and protects from the fly and dust dangers. If is of course essential that a pit or trench so filled in should not be disturbed for at least a few months; and so, before such places are abandoned, the earth is banked up over them, or the site marked, so that it may continue to be recognized as one in which excretal matter has been buried. There is the likelihood that this replaced earth may have received some contamination of urine, etc., and so a precaution sometimes adopted is to purify the top surface of a recently filled-in trench by burning a little dry camp refuse over it before the grass sods are finally replaced.

The trenching of fæces may endanger water supplies, and is unsuitable when the ground water reaches near to the surface; moreover, it may use up too much area of land.

Further, in the use of trenches or pits for the collection and burial of excrement, it is necessary to keep them protected against flooding by heavy rainfall. If they are placed on sloping ground, the highest-lying border of the latrined area is provided with a good surface-water trench to carry the flood waters past the area to lower-lying land—if possible, beyond the camp. Otherwise, heavy rainfall may be responsible for washing out excretal trenches or pits and spreading this dangerous matter over a portion of the camp area. It is to guard further against this danger, and also to shelter the men using the excretal trenches, that an awning or other protection from rain is generally provided. No pit or trench is ever allowed to overflow.

Urine trenches are made about 2 feet wide, in order to catch all the urine; they drain to a central soak-away pit filled with stones, etc. In the summer-time (and fly season) they should be lightly covered several times a day with earth, ashes, sawdust,

chloride of lime, or other disinfectant. There is much ground contamination involved in the use of night urinals unless the pails or cans are well raised above the ground by stones, etc., and painted white, so that their exact position can be made out at night. If night urine trenches are used, these are indicated by posts painted white. If circumstances permit, it is well to provide lantern lights to night urinals on very dark nights.

Where spilling is known to occur, it is wise to either burn some dry rubbish on the contaminated area every twenty-four hours, or else to keep it well sprinkled with cresol solution, chloride of lime, or other disinfectant.

In the case of less temporary camps, the surface on which excrement and urine pails stand is sloped and made of a hard, non-absorbent material, which can be washed down frequently. This arrangement, though it reduces, does not remove the danger from spilling.

Where excrement pails or buckets are used and earth is not added, it is a good plan to keep the excrement covered with a liquid disinfectant, but as this adds greatly to the difficulty of disposal, it is only done where the fly danger is exceptionally great.

Even when on the march it must be borne in mind that the route of to-day may be a line of communication to-morrow, and that it is important to prevent the fouling of the roadside. At every halting-place simple but suitable preparations, on the lines above indicated, are made for the men to ease themselves, and pickets or sanitary police supervise these arrangements, and see that everything is left safe and tidy before the column moves on. Simple improvised incinerators for the destruction of combustible camp refuse are made of brick, stones, clay, or sods of earth, with plenty of access below for air.

When soakage pits or trenches are made for sullage waters, cresol, chloride of lime, or other disinfectant is occasionally applied; and this should be done several times a day in the fly season. The greasy sullage waters from cook- and wash-houses are especially liable to cause nuisance and to attract flies; and the fatty matter tends to coat a pit or trench, and so prevent the water from soaking away. Therefore, in temporary camps, these waters are often first strained through straw, bracken, brushwood, or dry grass in a wire cage, which catch the greasy and soapy matter, etc.; and this straw, etc., is

removed and burnt, and fresh material substituted daily. The strained waters should be carried into a pit filled with stones or loose earth. It need hardly be said that the better sanitary arrangements possible in more permanent camps, whereby all these waste waters are conveyed beyond the camp in covered drains, are carried out whenever circumstances permit.

In more permanent camps, the method of fæcal collection and disposal which is commonly selected is a pail system, with the pail contents disposed of either upon land or by cremation in a destructor.

To avoid the objectionable features of the pail system, efforts have been made to provide for the *in situ* incineration of fæces. These have taken the form of trench incinerating latrines, in which brick walls a foot apart and four courses high are built with a chimney at one end. Each trench is covered with a hinged lid, and in use a man raises this lid, places his feet on the two walls of the trench, and allows the fæcal matter to drop into the trench. A small quantity of wood is placed in the trench, and when it is lighted, with or without the assistance of a little paraffin, it dries and ultimately burns to a clean ash. In the American pit method brushwood or shavings with paraffin are employed to support combustion. *In situ* extemporized incinerators of bricks, concrete, and tins or sandbags filled with clay and ashes were found to be efficient in the Great War. A simple and sanitary device (Macpherson) is to utilize divided biscuit or petrol tins, and for the dejecta to be received on to paper thus supported, the dejecta being subsequently placed by the men into a simple incinerator only a few yards distant, which is kept burning. In this method the urine passes away in front of the man into a drain which leads to a soak-away tip.

By such methods of immediate and *in situ* incineration cartage and spilling are avoided, and there is no fly danger; but the discipline and supervision of the men must be good.

By the *cremation* of the pail contents upon the camp area the expense of transport is materially reduced, but the other expenses involved combine to make the system costly. The arrangements made may take the form of either small unit destructors, capable of dealing with the daily fæces of a battalion, and located within the camp area; or a larger destructor, or destructors, to serve two or more units, placed on an outlying part of the camp to leeward of prevailing winds. In either case, satisfactory results

are dependent upon the employment of a considerable proportion of readily combustible material, a proper admixture of this material with the fæces, and the skilled feeding and working of the destructor. In addition to a certain amount of suitable dry camp refuse, sawdust, shavings, breeze, etc., generally have to be burnt with the fæces (or fæces and urine in some cases). With the small unit destructors the labour is less, mainly because they are disposed adjacent to the latrines, and so hand transport becomes possible.

It is usual to provide drains in many hutted camps to take the urine and sullage waters. But where this is done it is easily practicable in many cases to provide water-closets, and to thus install a complete water-carriage system for the camp. The urine and sullage waters have to be dealt with similarly to sewage, and the inclusion of the fæces, while necessitating some extension of purification plant, or of land for irrigation, tends to make the production of a suitable effluent more easy, and no extra hands are necessary for management purposes.

It is unnecessary to dwell at length upon the sanitary advantages of the water-carriage system over the other systems. It entails no handling of pails and no cartage of fæces, and therefore there is no spillage; and as the surface soil of the camp is kept free from such contamination, the fly and dust dangers, and the risk of boot-carried infection of the huts, practically disappear; and with them much opportunity for the spread of enteric fever when the disease is introduced into the highly susceptible camp population.

The best provision where long-standing camps are concerned is the complete water-carriage system; and, where this is impracticable, probably the pail system with small unit destructors placed close to latrines is, especially when worked by a military sanitary squad, the next best.

The following are the provisions made in military barracks:

Water closets or latrine seats	6 per hundred men.
Urinal stalls	4 ,, ,, ,,
Baths	1 ,, ,, ,,
Showers	4 ,, ,, ,,
Ablution basins	14 ,, ,, ,,

CHAPTER III

AIR AND VENTILATION

Pure atmospheric air, freed from aqueous vapour, has the following volumetric composition:—

Oxygen	20·94
Nitrogen	78·09
Argon	0·94
Carbonic acid	0·03
	100·00

The amount of aqueous vapour present in air is variable, the average in this country being 1·4 per cent.

Traces of organic matter, ozone, mineral salts, ammonia, nitric acid, neon, helium, krypton, xenon, hydrogen, and carburetted hydrogen are found in air; and in towns sulphurous acid and sulphuretted hydrogen.

Ozone, which is oxygen in an allotropic and highly active condition, is absent from town air; and it is doubtful whether it anywhere exists as a constituent of the atmosphere of any real importance.

This composition is, as regards the four gases which compose almost the entire bulk of ordinary air, remarkably uniform in every part of the world. Even in the midst of large cities, where the atmosphere is being polluted in many ways, the air of open spaces differs but very slightly in the proportion of its constituent gases from the air on the open plains, mountains, or seas, which is far removed from such sources of contamination. This is not to be wondered at when the immense power and universality of the forces which promote purification of the atmosphere are considered. Such are:—The wind, which dilutes and sweeps away impurities, bringing pure air in their place; the rain, which washes the air, carrying down in its fall dissolved gases and suspended impurities; the chemical effects of the oxygen and ozone in the air on the

oxidizable matters in it; and, lastly, the power possessed by the green parts of plants, in sunlight, of absorbing carbonic acid, fixing the carbon, and setting free the oxygen. The latter process is, however, reversed during the hours of night, CO_2 being evolved; but the balance is decidedly in favour of purification.

Confining our attention for the present to the outer air—the air outside buildings—it has been found in large cities that when the atmosphere is stagnant, and no wind is blowing, especially during fogs, the air of open spaces may contain only some 20·80 per cent. of oxygen, or even less, and the carbonic acid may exceed 0·06 per cent., with an increase likewise in organic matters. Such observations have been made in London and Manchester. In narrow closed courts or streets, surrounded by high buildings, the air has been found considerably more impure than the samples above given, which were taken from open spaces. The air of such places is stagnant and confined, as in a well; there is no circulation to effect a proper renewal of fresh air and dispersion of accumulated impurities, and sunshine rarely penetrates. Yet such is the only air supply attainable in thousands of the dwellings of the poorer classes.

We thus see that although in towns much may be done by constructing wide and airy streets, by preventing the undue aggregation of dwellings and their back-to-back construction, and by suitable restrictions as to their height, to provide for proper ventilation and purification of the atmosphere, yet its purity is liable to variations, which do not occur in the air of the open country. These variations may be only very slight in amount, but they are not unimportant. Their bearing on the health and vitality of the populations exposed to their influence is probably considerable.

Amongst suspended matters usually present in the air, to a greater or less extent, are minute particles of mineral matter (including common salt, especially near the sea), soot, dust of various kinds—in towns consisting largely of organic matters from horse droppings—textile fibres, vegetable débris, pollen of grasses and flowers in the early summer, the spores of various fungi and moulds, diatoms, bacteria and their spores, monads and amœbiform organisms—dead and living. The purest air, such as exists at considerable elevations on mountains and over the sea, contains but very little suspended matter. In

towns, especially manufacturing towns, the air often contains much soot and dust of mineral origin. The dust in the atmosphere provides innumerable nuclei for the condensation of moisture.

In towns, the amount of organic and mineral dust in the air will depend greatly on the efficiency of the scavenging and watering of the streets. The wind raises minute particles from the surface of the ground, and carries them often great distances before they are deposited. In this way infectious particles from domestic dust heaps and dried excreta may be caught up and carried into the air.

Air is vitiated by *respiration of men and animals; by combustion of coal, gas, oil, etc.; by fermentation and putrefaction of animal and vegetable organic matters; by various trade and manufacturing processes.*

Vitiation by Respiration.

An adult individual at rest breathes at the rate of about seventeen respirations a minute. At each respiration about 500 c.c. (30·5 cubic inches) of air pass in and out of his lungs.[1] The air in the lungs loses 4 per cent. of oxygen, which is absorbed by the blood in the pulmonary capillaries, and gains carbonic acid from the venous blood to the extent of 3·5 to 4 per cent. The nitrogen remains unchanged. In addition, the expired air is raised in temperature to nearly that of the blood, 98·4° F.; it contains 5 per cent. of aqueous vapour, and a trace of putrefiable organic matters.

The amount of carbonic acid which is given off by an adult male person at rest can be calculated from the above figures, and will be found to be 0·72 cubic foot in one hour. From actual experiment it has been determined that an average adult gives off quite 1 cubic foot of CO_2 during gentle exertion, and as much as 2 during hard work. The adult female gives off about one-fifth less of each of these quantities under similar circumstances, and an infant is said to give off about 0·5 cubic foot of CO_2 per hour. In a mixed assembly at rest, including

[1] $\frac{17 \times 30{\cdot}5 \times 60}{1728} = 18$ cub. feet breathed per hour.

4 per cent. of 18=0·72 cub. foot per hour of CO_2.

male and female adults and children, the CO_2 given off per head is therefore taken as 0·6 of a cubic foot.

The repeated occupation of overcrowded, ill-ventilated rooms by human beings tends to the production of a lowered state of health and favours the onset of disease. Recent experiments have demonstrated that the *physical changes* in the air are mainly responsible for these results.

These experiments included a number of tests made in a specially constructed glass chamber in which the physical and chemical qualities of the air could be rigorously controlled. It was found that with a respiratory impurity of carbonic acid exceeding any recorded up to that time as having been found in the air of a crowded room—*e.g.*, from 1·0 to 1·5 or even 1·7 per cent.—no injurious property of the air could be demonstrated so long as the temperature and humidity were kept low; and that under these circumstances the absence of any disturbance was so complete that the power of co-ordination remained intact—as was proved by the ease and normal manner in which certain arithmetical calculations given by way of test were carried out. Parallel results have been obtained in the case of schoolrooms crowded with children, but in which the temperature was kept low.

On the other hand, as soon as the temperature and humidity were increased to beyond certain limits, there appeared in normal persons who were submitted to experiment the usual symptoms that occur when people are crowded together in one room—*i.e.*, feelings of drowsiness and headache, oppression, lassitude, giddiness, nausea, etc. These symptoms, however, could be relieved at once simply by reducing the temperature and humidity of the air to normal. Contrivances were adopted for varying the quality and the quantity of the air within the chamber. Sometimes tubes leading from the chamber to the outside air have been provided, and it was found that when subjects were affected by the atmosphere of the chamber they obtained no relief by breathing through this tube, whereas if they stepped outside of the chamber relief came at once. Again, if a subject breathes through a tube the stale hot air of the chamber, while standing outside of it, no unpleasant symptoms appear. Even when sitting in the chamber relief is experienced when the air is set in motion by fans. These experiments have been repeated, with slight modifications, by several independent workers, and the

results have always been in strict conformity. They establish the fact that the evil results of close, ill-ventilated rooms are not due to respiratory impurities accumulating in the frequently re-breathed air, but to its altered physical characters. The harmful results may be attributable to "heat retention." By "heat retention" is meant the partial abeyance of the normal bodily function of ability to lose heat by radiation and evaporation from the surface of the skin.

If the air is stagnant and still, the moisture-laden emanations from the body are imprisoned and entangled by the clothing, and a humid layer of foul air hinders further evaporation; while if the air around the body can be sufficiently removed, evaporation continues its beneficent work of throwing off waste products and regulating the body temperature. Doubtless this circumstance explains the sanitary effect of electric fans which do not subserve ventilation, but simply keep the air in motion.

Haldane's experiments as to the precise point at which the effect of air temperature on humidity is reflected by a definite rise in body temperature show that in a still atmosphere the point is a wet-bulb temperature of 88° F., and in moving air one of 93° F. When muscular work is performed, 80° F. may be the limit in a still atmosphere.

It is not the actual temperature of the air so much as the rate at which the skin surface can cool which affects our well-being and influences our sensations of comfort. Prof. Leonard Hill has therefore contrived an instrument for showing the rate of heat loss at a temperature approximating to that of the human body—the Kata-thermometer. It consists essentially of a large-bulbed spirit thermometer graduated from 90° F. to 110° F. with distinctive marks on the stem at 90°, 100°, and 110°. Two such instruments are generally employed, one with the bulb uncovered (the dry Kata-thermometer), the other with the bulb covered with open-mesh cotton material. To employ the instrument, the bulbs are immersed in water at about 150° F. until the spirit rises into the small bulb at the top of the instruments. The excess of water is then jerked off the wet bulb, and the other instrument is dried. Both instruments are then suspended in air, and the rate of cooling from 110° to 110° F. and from 100° to 90° F. is taken with a stop-watch. The wet bulb loses heat by evaporation—the dry bulb by radiation and convection. The instrument has been graduated by taking many observations

under a great variety of conditions, both indoor and outdoor. The readings obtained under conditions which appear to the sensations as ideal have been taken as the empirical graduation of the instrument. Such indoor readings, in particular, give the standard to be aimed at in the heating and ventilation of buildings. Each instrument has a factor into which is divided the number of seconds taken by the spirit to fall from 100° to 95° F. This gives the rate of cooling at body temperatures in milli-calories per square centimetre per second. To secure comfort, the cooling power of the atmosphere, as determined by the wet Kata-thermometer, should probably be between 20 and 30 milli-calories per square centimetre per second. The actual figure will depend on the prevailing climatic conditions; for these determine the standard to which our bodies are tuned.

Increase of Carbon-dioxide Gas.—In the air of an inhabited room the amount of CO_2 is always increased, as compared with pure air; and this increase is directly proportional to the number of persons present, and inversely proportional to the volume of fresh air introduced by ventilation. But the increase of CO_2, even in crowded and badly ventilated rooms, is comparatively speaking a small matter. The amount of CO_2 by volume in pure air being from 3 to 4 parts per 10,000, in inhabited rooms the proportion of CO_2, even where there is excessive crowding and very defective ventilation, as in some elementary schools, seldom rises above 50 volumes per 10,000, and it requires about six times as much (300 volumes per 10,000) to produce an immediately perceptible effect on the respiration, as shown by increased depth and frequency of breathing (Haldane); whilst no poisonous effects appear to be produced until the proportion of CO_2 rises to 500 volumes per 10,000, or 10 times the amount ever likely to be found in inhabited rooms. There is always about 6 per cent. of CO_2 in the residual air of the pulmonary alveoli (Haldane and Priestley). An increase of CO_2 in the respired air stimulates the respiratory centre to induce increased pulmonary action, so that the percentage of CO_2 in the alveolar air remains constant. The alteration in the breathing induced by respiring air containing 50 volumes of CO_2 per 10,000 is quite inappreciable. A slight muscular exertion, such as that of walking at the rate of 3 miles an hour, would produce many times as much effect on the breathing. From these facts it may be inferred that the increased CO_2 in the air

of inhabited rooms is not of itself productive of injury to health.

There is a very definite relationship between the sense impressions of the state of the atmosphere and the percentage of CO_2 in the air. This sense impression is probably one of the most reliable guides in judging of the condition of an atmosphere. It is the summing up by the individual's senses of everything that makes for the production of unhealthy conditions, whether this be temperature, excessive moisture, or lack of movement in the air. It was found by Wilson Jameson that, when the CO_2 percentage exceeds 0·1 in occupied Army huts, there is usually a sensation of stuffiness, and that sense impressions in conjunction with the percentage of CO_2 constitute satisfactory means of drawing a trustworthy conclusion as to the state of the air. He found that the Kata-thermometer readings failed to reflect equally well the variations of atmosphere, and the number of men and the number of open windows in the occupied huts examined.

Diminution of Oxygen.—The diminution of oxygen in air vitiated by respiration has been the subject of experiment, but in no case has the reduction been found to be more than trifling. The normal amount of oxygen in pure air being 20·94 per cent. by volume, instances have been recorded where the oxygen has been reduced to 20·65; but it can hardly be supposed that such a reduction can exert any influence on health, having regard to the fact that many mountain climates are notoriously healthy at altitudes where the diminution of atmospheric pressure corresponds with a very much greater reduction in the percentage of oxygen.

The oxygen in the air of the alveoli of the lungs forms normally from 13 to 14 per cent. of such air.

Organic Matter.—For many years it was believed that the injurious effects due to the breathing of air vitiated by human respiration were attributable to organic matters contained in expired air. It was supposed that these organic matters were partly suspended in the air, consisting of small particles of epithelium and fatty matters from the mouth, and in part were in the form of an organic vapour from the lungs and air-passages which was held to be nitrogenous in character and poisonous when rebreathed. The experiments, however, of Berger, Weir Mitchell, and Billings in the United States, and of Haldane

and Lorrain Smith in this country, tend to show that there is no volatile organic poison in expired air; whilst there is no definite proof that the tests for the presence of organic matter in air vitiated by respiration are any indications that the source of such matters is the air expelled from the lungs. The reducing action of vitiated air upon permanganate of potash may be due to other constituents of such air than organic matters; and the fact that the washings of such air with distilled water yield on distillation, ammonia, and albuminoid ammonia in excess of that present in pure air, does not necessarily mean that the organic matters, of which these ammonias may be taken as evidence, are invariably derived from the lungs. They may, in fact, be due to volatile products given off from the teeth and gums, from dirty skins, and from excretions adhering to foul clothing. More exact research is required to ascertain the organic constituents (if any) of expired air, and to differentiate them from the volatile products of decomposition arising from the general surface and other parts of the body.

Personal Emanations.—These emanations are undoubtedly very largely responsible for the unpleasant odours which are perceptible on passing from the outer air into a crowded, unventilated room, more particularly when the occupants are persons of uncleanly habit. No sufficient experiments have been made, nor are there perhaps any satisfactory tests known which could determine the nature and quantity of the volatile matters to which these odours are due. It is possible that the deleterious action of air vitiated by the presence of human beings may be to some extent due to the presence of these odoriferous volatile substances, minute in amount though they be. It is conceivable that the long-continued action of such substances on the olfactory nerves may ultimately induce through the central nervous system physiological disturbances which are inconsistent with the maintenance of good health.

The tendency to an increased output of foul-smelling volatile products from the bodies of the occupants of a room is materially increased by a high temperature and an atmosphere approaching saturation from the presence of moisture given off in the breath.

Micro-organisms.—It is now known that during ordinary quiet breathing, micro-organisms are not given off from the air-passages to the expired air; but that the respiratory efforts associated with laboured respirations, such as coughing, sneezing, and loud

talking, are characterized by the spraying of microbes present on the mucous membranes of the air-passages into the air. Most of the microbes so given off are harmless and incapable of affecting the health of those who breathe such air; but at times the infective organisms of nasal and laryngeal catarrhs, of influenza, diphtheria, tuberculosis, and other diseases, are thus ejected from the air-passages, and may be the means of propagating these diseases. Apart, however, from the occasional presence of definite pathogenic bacteria, the number of harmless organisms in the air we breathe does not appear to be very material. A small number of germs per litre of air is more an indication of cleanliness of the apartment and the absence of dust than of efficient ventilation and the avoidance of respiratory impurity.

The number of microbes present in air vitiated by respiration seems to bear no very definite relation to the amount of CO_2 gas present. This is not to be wondered at when we know that the greatest numbers of microbes are found in the air which contains the largest amount of dust, and that the air of inhabited places may be stagnant and therefore comparatively free from dust, although much polluted by respiration. It appears also that the microbes and dust particles in the air we breathe do not as a rule reach the lungs, but adhere to the moist membranes lining the mouth, nose, and throat, and are got rid of by the mucous excretions of these membranes. The air reaching the lungs is consequently, as a rule, sterile; and the expired air in gentle breathing is also devoid of organisms. It is probable that the infective organisms present occasionally in the air are absorbed into the system, after being deposited on the mucous surfaces of the nose, tonsils, or palate, and only occasionally reach the air cells or bronchi of the lungs.

On the whole, then, it would appear that possibly there may be some constituent of air vitiated by human respiration and transpiration, which may contribute to the injurious action of such air upon health; but this constituent has not yet been identified. It hardly seems probable that a raised temperature and excess of moisture, or the presence in the air of non-pathogenic micro-organisms from the air-passages, would be able to give rise to those far-reaching effects that the continued respiration of foul atmospheres is known to produce. Whilst nothing of any importance appears to be given off to the air by human

respiration and transpiration, may not the air by such means be deprived of some vital element with which we are unacquainted ?

Modern physiological research places especial emphasis on movements of masses of air at somewhat different temperatures as being essential to the continuous stimulation of the surface cutaneous nerves of the body, on which health and comfort so largely depend. The warm stagnant atmosphere is relaxing and depressing, whilst the atmosphere displaying continuous gentle movements, owing to slightly varying temperatures in different parts or at different levels, is both stimulating, refreshing, and healthful. In the latter case, the cutaneous stimulation assists the circulation of the blood in the cutaneous vessels; in the former, the absence of any stimulation, combined with excessive heat, leads to cutaneous vascular stagnation and retention of waste products in the blood, the latter being the cause of the lassitude and depression experienced by the occupants.

The continued breathing day after day of "stuffy atmospheres" is apt to produce headache, inability to concentrate the attention, drowsiness, lassitude, depression of spirits, loss of appetite, dryness of the throat and nose, with consequent thirst, a tendency to "take cold" easily, and in some cases actual fever has been produced, or a diminished resistance to the onset of influenza and other infectious diseases.

It must not be supposed, however, that it is healthful to be in a room with a "thorough draught." In such a case, either the movement of air is too great, or the temperature of the moving air is too far below that of the bulk of the atmosphere in which the person is sitting. The effect of a "thorough draught" is to cause too much stimulation of the cutaneous circulation, with the result that the cutaneous vessels contract and drive the blood to the internal organs, leaving the skin cold whilst the internal organs are unduly congested. Chills are thus induced, which may have serious results and be the precursors of illness. The chill certainly seems to render the body less resistant to the invasion of pathogenic micro-organisms, which may be present at any time in the mucous membranes of the upper air-passages. Many people prove resistant to chill if the body faces a cold current of air, who succumb if the back and loins are unduly cooled.

The state of the air in dwelling rooms depends upon the amount of cubic space for each individual and the facilities

afforded for the entrance of fresh and the exit of foul air. Where these points are properly attended to, the air, although rather more impure than the external atmosphere, will not be productive of injury to health. In those extreme cases where many people are temporarily crowded together and the ventilation is totally inadequate, the air often becomes sufficiently affected to cause headache, lassitude, nausea, and fainting, and these phenomena may be regarded as largely due to heat retention. Mental and physical tests also demonstrate a material reduction in mental and muscular efficiency.

The long-continued occupation of overcrowded and insufficiently ventilated rooms is, probably, one of the causes of rickets in children, and tends to produce a lowered state of vitality, characterized by anæmia, dyspepsia, and lassitude, in older people. People in this lowered condition of health, which is very common amongst those who spend the greater portion of every day indoors, in crowded offices, schools, workrooms, and factories, offer much less resistance to attacks of acute disease than do people who live more out-of-door lives; and they are greatly more subject to all chronic and wasting diseases. Dr. Ogle's researches have shown that, of all the industrial classes, those which are the healthiest and have the lowest death rates are the gardeners, farmers, agricultural labourers, and fishermen —those, namely, whose occupations are carried on in the open air. The death rate from phthisis in these classes is only half that of the male community generally, and they enjoy about the same amount of freedom from diseases of the respiratory organs. Differences in food or housing accommodation cannot account for the comparative freedom of these classes from pulmonary disease.

The relationship subsisting between foul air, produced by overcrowding and insufficient ventilation, and phthisis is now generally recognized. The most convincing proofs of this are to be found in the comparative immunity enjoyed by soldiers, sailors, and prisoners at the present time from this disease. Formerly, owing to the very limited amount of cubic space allotted per head, and the disregard paid to ventilation, phthisis was considerably more prevalent among soldiers, Royal Navy sailors and marines, and prisoners in His Majesty's gaols, than amongst the males of the same age in the social classes from which they were taken. At the present time, other conditions, such as food,

exercise, etc., remaining much the same, but more air-space and better ventilation having since been provided, the death rate from phthisis is considerably less amongst these servants and prisoners of the State than amongst the civil population.

The excessive incidence of disease on the inmates of back-to-back houses, in which there can be no through ventilation and circulation of air, has been well established.

Acute diseases of the air-passages, especially catarrhs, bronchitis, and pneumonia, are excessively prevalent among those who live in heated, overcrowded rooms.

The zymotic diseases generally are more prevalent amongst overcrowded populations than amongst those who are better lodged; but this is accounted for by the greater ease with which contagion can pass from the sick to the healthy.

There is, however, evidence that insufficient air-space and defective ventilation of school dormitories and classrooms tend to favour inflammatory conditions of the throat (follicular and ulcerative tonsillitis), which in some instances, as the outbreak progresses, may be indirectly responsible for attacks of true diphtheria. The defective ventilation induces the unhealthy throat conditions; and the subsequent appearance of diphtheria may, as Thorne supposed, be due to progressive development in type of the throat organisms; or, as is more probable, it may merely be due to the accidental introduction of the true *Bacillus diphtheriæ*, which at once assumes virulence under the prevailing morbid throat conditions.

In the air of ill-ventilated sick-rooms and hospital wards the débris of dried epithelial scales and pus cells may often be found floating. These matters are especially frequent in wards where many of the patients have purulent discharges from suppurating wounds or copious expectoration from the lungs, and are usually accompanied by an abundance of spores of fungi and bacteria and large excess of organic matters in the air. In many persons the breathing of such polluted air produces an immediate effect on the throat and tonsils, passing sometimes into acute tonsillitis or hospital sore throat. Its effect in increasing the severity of, and in retarding recovery and convalescence from, acute disease is now generally recognized. Patients suffering from erysipelas, ophthalmia, pyæmia, septicæmia, and hospital gangrene, are undoubtedly infectious to those who have open wounds. The contagious particles (pyogenic micro-organisms of various kinds)

—contained in dried epithelial scales and pus cells—may be transferred through the air from patient to patient; and often no measure short of emptying the ward appears to be of any avail to stop an epidemic once begun. In times not very far distant, these diseases were, in the surgical wards of many hospitals and infirmaries, almost constantly present. Freer ventilation, improved sanitary arrangements, and the aseptic treatment of wounds and injuries, have almost eradicated such calamities from modern hospital practice.

It is possible that parasitic skin diseases may spread through the air, for sporules and mycelia of *Tricophyton tonsurans* and *Achorion Schönleinii* have been found floating in the atmosphere of wards occupied by patients suffering from diseases of the skin.

Vitiation by Combustion.

There are three kinds of mineral coal—lignite, anthracite or smokeless coal, and bituminous coal. Lignite is a deposit intermediate in its characters between peat and coal. In some parts of Germany, considerable deposits occur; and it is there often used both for domestic and manufacturing purposes. It is a poor fuel compared with coal. Bituminous coal is used exclusively in the manufacture of illuminating gas; it usually furnishes about 59 per cent. of solid carbon (smokeless), 33 per cent. of volatile hydrocarbons (smoke producing), and 8 per cent. of ash. Anthracite is a sort of natural coke, most of its gases having been driven off during the process of formation. Bituminous coal is generally used for domestic fireplaces, although anthracite, being smokeless (no soot), when used in properly constructed stoves, would be far preferable. Bituminous coal when burnt in an open fireplace gives off nearly three times its weight of carbonic acid, small quantities of carbonic oxide, sulphurous acid, bisulphide of carbon, sulphuretted hydrogen, and steam. About 1 per cent. is given off as fine particles of carbon or soot and tarry matter. One pound of coal requires 240 cubic feet of air for complete combustion.

Illuminating gas is obtained by the destructive distillation of coal in closed retorts, without access of air. The gas is subsequently purified by condensation to remove tar and water, and its temperature is reduced to about 60° F. If the temperature of the gas is lowered below 58° F., naphthaline and other

valuable illuminants are deposited, and the gas is impoverished. The crude gas is then passed through coke scrubbers, which are large chambers so arranged as to offer an extended surface, constantly sprayed with water, to the gas. The water absorbs from the gas nearly the whole of the ammonia and the remaining tarry matters, whilst a certain quantity of the ammoniacal and sulphur compounds are removed. This water impregnated with ammonia and its compounds forms the "gas liquor" or crude ammoniacal liquor of commerce, which is conducted to the tar well. The gas is then led on to the purifiers, formed of lime or sesquioxide of iron, or both, and here the carbonic acid, sulphuretted hydrogen, bisulphide of carbon, sulphocyanides, and other offensive sulphur compounds, are removed, or at least reduced in the gas to a practically unimportant quantity. Thus the "spent lime," which absorbs cyanogen and sulphur compounds in addition to sulphuretted hydrogen, is peculiarly offensive. The purified gas is stored in gasometers, which are sunk in the earth to a considerable depth, water being used as a seal to prevent the escape of the gas. The standard adopted by the Metropolitan Gas Referees requires all gas to be quite free from sulphuretted hydrogen; the maximum of sulphur (in compounds other than H_2S) must not exceed 17 grains per 100 cubic feet, nor the ammonia 4 grains per 100 cubic feet.

When purified, coal gas contains, on an average: hydrogen, 46 per cent.; marsh gas, 37 per cent.; carbonic oxide, 7 per cent.; illuminants (ethylene, acetylene), 5 per cent.; nitrogen, sulphurous acid, etc., 5 per cent. The products of combustion of coal gas are carbonic acid, 50 to 60 per cent.; water, 16 per cent.; variable traces of carbonic oxide—least when combustion is most perfect—sulphurous acid and ammonia. One cubic foot of average gas combines with the oxygen of from 5 to 8 cubic feet of air, and produces when burnt about $\frac{1}{2}$ cubic foot of CO_2, and from 0·2 to 0·5 grain of SO_2; and it is able to raise the temperature of 31,290 cubic feet of air 1° F.

A common gas burner consumes on an average about 4 cubic feet of gas per hour, and furnishes, therefore, about 2 cubic feet of CO_2 in that time. If this CO_2 is to be brought down to 0·6 per mille, 10,000 cubic feet of fresh air would have to be supplied per hour for each such burner. But this is not necessary; and indeed, when adequate measures are adopted for purifying coal gas, its products of combustion contain but little impurity

besides CO_2. It is therefore generally considered that about 1,200 cubic feet of fresh air supply is amply sufficient for every cubic foot of gas consumed. A "standard" sperm candle (six to the pound), and burning 120 grains per hour, gives off about 0·4 cubic foot of CO_2 per hour; and one cubic foot of CO_2 is produced by the combustion of about 300 grains of oil in a lamp.

The sulphurous acid in the air of towns, where coal is largely consumed, may cause the rain to be acid, and has a very destructive effect on vegetation, mortar, and the softer kinds of building stone. The products of combustion of coal gas usually escape into the air of the rooms where the gas is burnt, and serve to intensify the ill-effects on health of air already vitiated by respiration. Carbonic acid when present in the air, even to the extent of 2 per cent., if unmixed with other impurities, appears to have little, if any, effect upon health; but above this quantity it may produce headache and nausea, and if present to the extent of 10 per cent., or even less, it may produce rapidly fatal results. Carbonic oxide, on the other hand, is very poisonous. As little as 0·3 per cent. in the air may cause death from asphyxia, the gas uniting with the hæmoglobin of the red corpuscles and displacing the oxygen, so that the red corpuscles can no longer act as carriers of oxygen to the tissues, and failure of the chief nervous centres results. It therefore acts as a powerful narcotic, and exerts its effects in a most insidious manner; for being destitute of odour and not causing any irritation of the air-passages when inhaled, it may be breathed unconsciously by the victim, who quickly experiences a loss of the power of movement, and even of any desire to make an effort to escape from the poisoned atmosphere.

The sulphurous acid and soot in the general air of towns like Manchester, Liverpool, and London, appear to have no very marked effect on healthy people; but they are undoubtedly injurious to many asthmatics and to people suffering from bronchitis. The temperature near the ground is usually higher than at some distance up, and thus hot air rising passes from warm to cold air; and, although on rising it expands and cools, it may always be warmer than the surrounding air, and can thus continue to rise. If, however, the temperature gradient is reversed and it is cooler near the ground than higher up, the rising gases from a chimney may soon reach air of a temperature as

high as their own, and thus can rise no higher. The smoke collects at this level, and we have a smoke fog. Whether the smoke lies down in streets or hangs as a cloud overhead will depend upon the temperature distribution (Owen). During dense fogs the mortality from lung diseases always greatly increases. Yellow town fogs are due to the suspended particles of moisture in the air (which constitute a mist) becoming enveloped in a greasy coat of mixed carbon and hydrocarbons. The mist is thus rendered yellow and opaque, the light of the sun cannot penetrate, whilst the sulphurous products contained in the fog are extremely irritating to the respiratory mucous membranes.

Corfield has called attention to cases of relaxed and ulcerated sore throat caused by slight escapes of coal gas into houses by defective pipes and burners. Coal gas also occasionally finds its way into houses from leaky or fractured mains in the street. The gas passes through the soil and escapes under the basement floor, or even finds its way up the walls behind panelling. When the escape is large in amount, the effects produced on persons inhaling the gas are of an asphyxial type due to the contained carbonic oxide; but when the escape is small, but long continued, the sulphur compounds, and especially the bisulphide of carbon, appear to be the injurious factors affecting the throat. These effects of escape of gas would probably be most intense where the gas is insufficiently purified after manufacture.

The method usually adopted for testing the soundness of gas-pipes and fittings is to subject them to air pressure by means of a force pump. A pressure gauge is attached to one of the burners, and air is forced into some other connected pipe until a pressure of 5 or 6 inches of water is registered on the gauge, when the stopcock on the force pump is closed. If the pressure gauge reading is not maintained during a few minutes, the pipes or fittings are unsound.

Foul-smelling sulphur compounds may also gain access to the atmosphere of occupied rooms from defective chimney flues. In testing a chimney flue, the outlet should be sealed from the roof, and one or more smoke rockets discharged from the fire-place opening, which must be sealed with a large piece of gummed paper immediately after the lighted rockets have been placed up the chimney; the smoke will then escape at any defective parts of the flue.

Vitiation of Air from Decomposition of Organic Matters.

Animal and vegetable organic matters in cesspools and in badly constructed sewers and drains ferment and putrefy, disengaging gases, some of which are fœtid and highly complex bodies, probably carbo-ammoniacal and allied in chemical constitution to the compound ammonias (methylamine and ethylamine), whilst others are the simple gases, carbonic acid, sulphuretted hydrogen, ammonium sulphide, carbon bisulphide, carburetted hydrogen, nitrogen, etc. Recent research tends to show that the organic vapours arising from decomposition of animal substances may contain traces of the animal alkaloidal substances—ptomaines and leucomaines—which are contained in the decomposing fæcal and urinary excretions of the animal body, and which may exert a directly poisonous action on the system. The carbo-ammoniacal vapours have a strongly offensive odour, and are found in the air of cesspools and sewers where fermentative processes are in action. The suspended particles in cesspool or sewer air are dead organic débris and living organisms (bacteria, moulds, and fungi, and their spores).

The micro-organisms—the bacteria and fungi—are constituents of sewer air to which attention has been lately most directed. The net result of these observations goes to show that, contrary to what might have been expected, sewer air is under ordinary conditions remarkably free from the microbes which are capable of cultivation on solid nutrient media at ordinary temperatures. By ordinary conditions are meant sewers of modern construction, well laid with good gradients, and therefore comparatively free from deposits.

Several observers have shown that sewer air generally possesses a relatively less number of microbes, capable of forming colonies on cultivation, than the atmospheric air outside; and Mr. Parry Laws' investigations tend to prove that the microbes in sewer air are derived from the organisms usually present in atmospheric air, and are not identical with those found in sewage. The microbes in sewer air are chiefly moulds, whilst those in sewage belong to the class of bacilli. The explanation appears to be that the internal walls of sewers are more or less wet or moist, and it is assumed, probably with reason, that the microbes in the sewer air adhere to the damp surfaces, and are thus prevented from floating in the air. This reasoning is strengthened by what is

already known of the presence of microbes in atmospheric air generally; for in dusty dry weather they are found in far larger numbers than in damp weather or after rainfall. In well-made sewers the sewage is borne away from the houses in a fresh and undecomposed condition; but in old and defective sewers, and even in moderately good ones when the temperature of the air is high, and the amount of diluting water is small—as during hot and dry summers—putrefactive bacteria undergo enormous multiplication, fermentative changes are set up in the sewage, and gases are formed which bubble up and break upon the surface of the liquid.

It was demonstrated as long ago as 1871 by Professor Frankland that liquids flowing smoothly in channels give off no solid particles to the air, and that even considerable agitation resulting in frothing may not cause any perceptible increase of the solid particles in the superincumbent air, but that the bursting of bubbles of gas in a liquid had a marked effect in disseminating solid particles. The experiments of Haldane and Carnelly, which have been more recently made, also show that splashing in a sewer, which may be caused by branch drains entering near the crown of the sewer, is productive of dissemination of micro-organisms in the air.

The earlier investigations of Mr. Parry Laws and Dr. Andrewes on the micro-organisms of sewage and sewer air tended to show that sewer air has no power of taking up bacteria from the sewage with which it is in contact. The authors concluded that the possibility of the existence of the bacillus of typhoid in the air of our sewers is infinitely remote. They also experimented on the vitality of the bacillus of typhoid in sewage. They concluded, as the result of their investigations, that sewage does not form a medium in which much, if any, growth of the bacilli is possible under natural conditions. The death of the bacilli in sewage is probably only a matter of a few days, or at most one or two weeks. But this degree of resistance may, nevertheless, be sufficient to allow of their being carried in sewage to remote distances, and of their being able to produce disastrous results should they gain access to any water supply.

Horrocks found that *Bacillus prodigiosus* added to sewage may be recovered from the air of drains and sewers, even when the sewage is flowing smoothly and without splashing. In one experiment the *B. typhosus* was found in the air of a drain through

which the stools of an enteric fever patient had been slowly passed. He also recovered *B. coli* from the air of one of the main sewers of the town, about 10 feet above the flowing sewage. The experimental results obtained by Horrocks will tend to revive the opinion, formerly held, that sewer and drain air may be the means of spreading infective diseases, such as enteric fever, and diarrhœa. They also showed that the disconnecting trap on a house drain prevents the passage of bacteria present in sewer air into the house drains.

Horrocks concludes that specific bacteria present in sewage may be ejected into the air and carried by air currents through drains, sewers, and ventilation pipes by (*a*) the bursting of bubbles at the surface of the sewage, (*b*) the separation of dried particles from the walls of the sewers and pipes, and probably (*c*) by the ejection of minute droplets from flowing sewage.

The more recent work of Andrewes confirms that of Horrocks, for he has shown that under many ordinary circumstances characteristic sewage bacteria are to be found intermittently in the air of drains and sewers. The streptococci of drain air correspond with those of sewage, and only to a slight extent with those found in the outer atmosphere. Similarly the bacilli of the colon group obtained from drain air correspond with those present in sewage; fresh air contains practically no bacilli of this character. The bacteria derived from sewage probably form but a small proportion of the total bacterial flora present in sewer air, unless there is much splashing or agitation of the sewage in the vicinity. Still, they are liable to be present, even although their numbers are relatively small. Andrewes is of opinion that the failure to identify these organisms in sewer air in former experiments was due to the fact that the special selective media, which are now available for the cultivation of various classes of micro-organisms, were then unknown.

Chemical examination shows that sewer air is subject to wide variations. A sample of air taken from a choked sewer in Paris was found by Parent Duchatelet to contain only 13·79 per cent. of oxygen, and as much as 2·99 per cent. of sulphuretted hydrogen. The air of closed cesspools in Paris must often have been very polluted to have caused those symptoms of partial asphyxia from which the workmen employed to empty them occasionally suffered.

In the London sewers the air is generally fairly pure. The

most impure sample taken by Dr. Russell from the Paddington sewers was found to contain 0·51 vols. CO_2, 20·7 vols. O, and 78·79 vols. N in 100 vols.

Where the quantity of sulphuretted hydrogen has been relatively great, sudden death has in some instances resulted amongst those who have opened cesspools. The same results have followed when men have entered foul sewers. Unconsciousness may be produced when there is as little as 0·2 per cent. of H_2S in the air. Whenever it is necessary to enter an old or foul sewer (or cesspool) the following precautions should be taken: Open the lids of the two adjacent manholes and leave open for some time, so as to obtain free ventilation and dilution of the gas; then cautiously lower a lighted candle into the sewer, which must not be entered unless the candle burns brightly. If there is a likelihood of explosive gases being present in the sewer, a miner's safety lamp should be lowered, or a mouse in a cage; in the latter case, if the mouse is lively after ten minutes in the sewer, it will be safe for a man to enter it. Whenever circumstances appear to warrant it, the man should have a strong rope tied around his shoulders, so that he could be extricated by a comrade, who should always be in readiness; and if he should have to crawl along the sewer, a rope should also be securely tied to his ankles, so that he may be drawn back if overpowered by gas. For men overpowered by sewer gas the best remedy is artificial respiration, or oxygen inhalation, if available. Liquor strychniæ should be injected subcutaneously, and artificial warmth applied to the extremities.

The breathing of drain or sewer air undoubtedly at times produces injury to health. This is especially the case when people are exposed to escapes of drain or sewer air into houses for a long period. The dose of the poison may not be sufficiently great at any one time to cause the acute symptoms above described; but the long-continued inhalation of diluted sewer air, as in houses with defective drainage, tends to produce a general loss of health (especially in children), which is shown in various ways, as by anæmia, loss of appetite, prostration, diarrhœa, fever, headache, vomiting, or sore throat; or it may be that only a condition of depressed vitality is produced, which offers but slight resistance to attacks of acute disease.

Occasionally a severe form of tonsillitis attacks the occupants of a badly drained house. Symptoms of blood-poisoning, as

shown by boils and carbuncles, petechial rashes, glandular enlargements, lymphangitis, phlebitis, albuminuria, and fever, have been noted by some observers, and attributed to long-continued exposure to drain or sewer air escapes into houses. To what particular constituents of sewer air we are to attribute these and allied illnesses it is difficult to determine. The attacks of tonsillitis, diarrhœa, etc., are not protective from future attacks; and although there is some evidence of the "sewer air throat" being contagious and directly transmissible from person to person, it is equally likely that examples of apparently direct contagion are really due to exposure to a common cause.

Probably on account of the violent splashing in soil pipes, etc., there are more possibilities of conveyance of infection through the drainage system of a building than through the air of a sewer.

Diarrhœa and dysenteric diarrhœa are sometimes caused by breathing air contaminated by excretal emanations. This is one of the many causes of the summer diarrhœa which is so common in a hot and dry season in the badly drained districts of large towns.

When excretal or other offensive emanations are given off into the open air, they are much less liable to cause disease or injury to health than when they find their way into confined spaces, such as narrow courts or the interiors of houses. In the open air of the country they are rapidly diluted and oxidized, and rendered practically harmless. In this way we can account for the excellent health enjoyed by the workmen on sewage farms and by those who live in the neighbourhood, as well as by the men engaged at sewage works; but the process of habituation may also perhaps be partly responsible for such good results. There is some evidence that since the introduction of the septic tank system of sewage treatment, and the discharge of the putrid or septic effluent upon artificial filters (sprinkler beds) or upon land, the near neighbourhood of town sewage works has in some cases been depreciated by effluvia which are stated to be injurious to the health of the residents in the affected zone. Such effluvia may be carried at times a considerable distance by the wind; but only those residing within a short distance of the works are likely to be affected in health.

Grossly polluted rivers, which give rise during hot weather to most offensive emanations, may at times cause injury to health. The same may be said of effluvia from manure manufactories,

soap works, tallow works, and other offensive trades, and also of the effluvia from putrefying animal bodies, given off into the open air; it being a matter of experience that occasional attacks of sickness and diarrhœa and chronic distaste for food may be produced by offensive emanations, even when discharged at a height from lofty chimneys. The air of crowded graveyards and vaults may contain excess of CO_2 and organic vapours (carbo-ammoniacal); if such polluted air should rise from the soil and directly escape into buildings, it might cause sickness among the occupants; but when the vapours escape into the open air, even in the midst of towns, no marked injurious effects occur.

The air over marshes is impure from the large amount of decaying vegetation in the water and soil. Carbonic acid, sulphuretted hydrogen, and carburetted hydrogen (marsh gas), are generally present in some excess, together with decaying organic matter, both in the form of vapour and of suspended matter. The suspended matters in marsh air consist of vegetable débris, diatoms, algæ, fungi, bacteria, and other micro-organisms. In some marshes the air is very rich in H_2S, and the symptoms of anæmia and prostration have been held to be due to this fact.

Vitiation of Air in Industrial Occupations.

Two kinds of occupation have long been recognized as hurtful, viz., (1) those that give rise to mechanical or chemical irritation of the lungs by trade dusts or vapours; and (2) those in which the workers are exposed to a high temperature, and maybe to air with excessive moisture.

The long-continued inhalation of dust tends to produce disease of the lungs, especially bronchitis, emphysema, and interstitial pneumonia, and it predisposes to fibroid phthisis. The source of the dust, whether vegetable or mineral, is not so important as the character of the particles which compose it. The most injurious kinds are those whose particles are hard, sharp, and angular, which become impacted in the walls of the bronchioles or air cells of the lungs, are not easily expectorated, and set up irritation and chronic inflammation of the tissues around. The soft or rounded particles are not capable of doing nearly so much mischief. Coal-miners' lungs are often after death found to be black (anthracosis) from the impaction of fine particles of coal

dust in the pulmonary alveoli, without the individual having manifested any pulmonary symptoms during life.

The gases which usually give rise to complaint in manufacturing districts are as follows: Chlorine, hydrochloric acid, sulphur dioxide and sulphurous acid, sulphuretted hydrogen, fluorides and hydrofluoric acid, zinc fumes, arsenical fumes, phosphoric fumes, carbon bisulphide, and various organic vapours such as those from glue refineries, etc.

The methods of reducing the risks and damage from toxic gases, vapours, and fumes are by (1) condensation; (2) absorption by water or chemicals; (3) combustion; (4) forced ventilation and the discharge of the gases into the air at a great height.

From brickfields, organic vapours and CO_2, CO, H_2S, and SO_2 gases are evolved. Bricks are made of clay mixed with a small proportion of ashes. When bricks are arranged in the clamps in layers, alternating with the breeze or combustible material, the emanations from the burning material are very penetrating; and when dust-bin refuse is used to burn the bricks, the partially burnt organic vapours are highly disagreeable, and are perceptible at considerable distances from the brickfields. When bricks are burnt in kilns provided with flues there is far less liability to nuisance, as the products of combustion are more perfectly consumed. Kiln burning should be insisted upon in the case of all brickfields situated in the close vicinity of inhabited houses.

The Alkali Works, etc., Regulation Act of 1906 provides that 95 per cent. of the hydrochloric acid gases and vapours produced in alkali works must be condensed; and in each cubic foot of air, gas, or smoke escaping into the atmosphere there may be only $\frac{1}{5}$ grain of HCl. Each cubic foot of air, gas, or smoke issuing from sulphuric acid works must not contain acidity amounting to more than 4 grains of sulphuric acid (SO_3). The keeping apart of acid drainage and alkali waste is strictly enforced, and all waste substances must be got rid of without nuisance. Other works to which this Act applies are salt works, cement works, chemical manure works, nitric acid works, sulphate and chloride of ammonia works, chlorine works, bleaching works, and gas liquor works.

In the manufacture of alkali the chief nuisance arises from the improper storage and disposal of the "tank waste," which contains compounds of sulphur. In the process, common salt is decomposed by sulphuric acid, and the crude sodium sulphate

(" salt cake ") is mixed with chalk and coal and heated; sodium carbonate is thus formed, and the unburnt carbon and calcium sulphide darkens the mass, which is known as "black ash." The sodium carbonate is dissolved out by water, and the residue constitutes the " tank waste." The workers suffer from diseases of the lungs, bad teeth, and dyspepsia, mainly arising from the acid fumes of the salt cake; but the hydrochloric acid fumes are so diluted as to generally produce but little effect on the workers, though they injure surrounding vegetation.

The process of the manufacture of coal gas varies somewhat in different manufactories. The waste gas lime, containing the poisonous calcium cyanide in addition to sulphur compounds, gives rise to serious offence, and its removal from the tank causes considerable irritation to those engaged in the work. To prevent dust, the lime should be watered a little before being dug out from the purifiers, and removed as often as necessary. During removal it should be covered over with sacking.

Nuisance may result in the neighbourhood of gas-works by (1) smoke given off during the charging and drawing of retorts; (2) the generation of water-gas and steam when the red-hot coke is quenched with water, the steam being especially offensive when the coal used in the manufacture of the gas is of a sulphurous nature; (3) the escape of crude gas from the mouthpieces of the retorts; (4) the smoke given off from imperfectly carbonized charges when withdrawn; (5) the offensive lime refuse from the purifiers, where lime alone is used for the absorption both of carbonic acid and sulphur compounds. When exposed to the air, sulphuretted hydrogen and bisulphide of carbon are released from the sulphides and sulpho-carbonates of lime by the action of the oxygen and carbonic acid in the air, and a most offensive nuisance is created. When, however, sesquioxide of iron is used for removing the sulphur compounds, and the lime is used only for absorbing carbonic acid after the sulphur compounds are withdrawn, the nuisance is reduced to a minimum.

The atmosphere may also be polluted by offensive odours arising from certain trade processes, which may be briefly considered under the headings of " Offensive Trades " and " Trade Nuisances."

Offensive Trades.

The noxious or offensive trades specified in the Public Health Act, 1875, are those of a blood boiler, a bone boiler, a tripe boiler, a soap boiler, a tallow melter, and a fellmonger. In urban districts bye-

laws may be made regulating these trades "or any other noxious or offensive trade." The model bye-laws of the Local Government Board also specify the trades of a blood dryer, a leather dresser, a tanner, a fat melter or fat extractor, a glue and size maker, and a gut scraper. As to what will constitute "a noxious or offensive trade" other than those specified, it is held that the business, in addition to being proved noxious, must be *ejusdem generis* with those specified, and deal with animal matters in some form.

A blood boiler or blood dryer deals with fresh blood collected at slaughter-houses and knackers' yards. A fellmonger is one who prepares either recent or old foreign skins for the leather dresser. A gut scraper is one who scrapes the small intestines of swine and sheep for the purpose of making sausage skins, catgut, etc. A glue and size maker extracts the gelatine by boiling almost every kind of waste animal tissue, but more especially bones, hoofs, horns, and skin trimmings.

The various nuisances in the trades above referred to may be prevented or abated by the adoption and enforcement of sufficient bye-laws.

Such bye-laws should secure:—

1. Free access to the premises by any officer of the sanitary authority.

2. The restriction of such trades to suitable premises. Gut scraping, for instance, cannot be carried on, as it sometimes is, in small houses without giving rise to offence.

3. The maintenance in good order of the drainage, lighting, and ventilation of such premises, and the proper cleansing of them. The floors or pavements should be kept in good repair so as to prevent absorption of any liquid filth, and should be swept or washed at the close of every day, and all splashings should be removed. The walls and ceilings should be hot limewashed twice a year at specified periods (say the first weeks of April and October), after all splashings have been wiped off; and the walls must be rendered non-absorbent of any liquid filth or refuse to at least the height to which such splashings may reach.

4. The proper conveyance to the premises, and storage on the premises, of the material used, so as to prevent the escape of noxious and offensive emanations. In some cases the material should be brought to the premises in non-absorbent covered receptacles, and stored in special closed compartments ventilated into a tall chimney flue by means of an air shaft provided, if necessary, with a gas jet or fan. Sometimes the materials to be stored should be dried, or treated with milk of lime, or even sprinkled with a little carbolic acid solution (1 in 40). Stored fat should be dried and laid out on racks in a cool room; and the materials used for glue making should be stored as dry as practicable, or treated with a sufficient quantity of milk of lime and closely stacked.

5. The best practical means of rendering inert the vapours emitted during the carrying on of the process. Where melting and boiling are performed, this should be done in steam jacketed pans, so as to guard against the higher temperatures which burn the fat, etc., and give rise to the formation of most offensive empyreumatic odours.

Large hoods communicating by pipes with the furnace flue should be used to collect the vapours given off from the contents of the pans during the boiling; and the chimney by which these fumes escape should either be carried up to a considerable height, or the vapours should be condensed in a suitable condensing apparatus,[1] or conducted into the furnace fire and cremated. This cremation may also be effected by means of a small " cremator " placed in the chimney.

The fumes arising from steaming bones, meat, etc., can be prevented by applying cold water directly after their removal from the boiler.

6. All filth and refuse matter to be collected in a sufficient number of non-absorbent vessels with close-fitting covers, and removed from the premises forthwith. Fellmongers and others must not keep uselessly decomposed skins, etc., on the premises.

7. All water used for soaking skins, etc., to be removed sufficiently often (at least once a day) to prevent effluvia arising therefrom, and all pits used for holding such water to be rendered water-tight. This bye-law will apply to the trades of a fellmonger, gut scraper, and leather dresser.

8. All waste lime to be removed with reasonable dispatch in covered receptacles, as also all other wastes or useless material.

9. All implements and receptacles to be kept sweet and clean. The floors and receptacles in some cases to be sprinkled or washed with some deodorant, as in gut scraping.

10. Penalties for offending.

The discharge of waste liquor into drains at a temperature exceeding 110° F. has often given rise to great offence from the sewer ventilators. This is now prohibited by statute (the Public Health Act Amendment Act, 1890), and all hot liquid refuse must be allowed to cool before it is discharged into a drain.

Trade Nuisances.

Fish frying.—Nuisances arise from the neglect to adopt proper means of collecting the effluvia and dealing efficiently with them. The effluvia are increased by (1) the prolonged use of the same oil for cooking purposes, (2) the burning of the oil and consequent production of empyreumatic odours, when the heating is done over an open fire.

These nuisances are best prevented by using the best dripping instead of oil, and by supplying a large deep hood to collect the effluvia arising from the frying. The hood should lead by a shaft into a fairly high chimney, and it is often necessary to provide a gas jet at the mouth of the shaft leading from the hood, so as to promote draught. To obviate the burning of the oil, the frying should be done in a deep vessel containing from 6 to 10 inches in depth of oil, or preferably steam jacketed cylinders should be employed. It is

[1] A cheap and satisfactory condenser can be made by taking ordinary drain pipes and packing them with pieces of coke, over which water is allowed to trickle in a constant stream; or the vapours may be absorbed in a water spray, or by being brought in contact with trays of water, as in a " scrubber."

rarely, if ever, necessary to cremate the effluvia in the fire, or to absorb them in the water of a " washer " or condenser.

Knackeries.—A knacker is properly a horse slaughterer, but he also slaughters other old and diseased animals, and receives the carcasses of those which have died of disease or accident.

Nuisances arise from the cries of the animals prior to their slaughter, for they are commonly kept several days; the filthy way in which they are sometimes kept; the undue and improper storage of material on the premises; the general unsuitability and filthiness of the premises; and the processes of bone boiling, flesh boiling (for cat's meat or fat extraction), or gut scraping, etc., which are sometimes carried on in the same premises.

Pig keeping.—This trade may become a nuisance from the improper storage of sour, malodorous food, with which the pigs are frequently fed, and from the effluvia from the sties. The sties should always be placed at a considerable distance from houses—at least 100 feet in urban districts. They should be floored with hard, impervious, and jointless material (*e.g.*, concrete), laid to a good fall towards a channel leading to a gulley which discharges into a drain or covered cesspool. The feeding material should be kept in impervious vessels with close-fitting lids, and the sties should be swept out and cleansed daily.

Artificial manure making.—The materials used are: (1) All animal waste materials from the offensive trades above referred to; (2) mineral matter, *e.g.*, sulphate of ammonia, nitrate of soda, gypsum, etc.

" Superphosphate " is made from a mixture of mineral phosphate and ground bones, treated with sulphuric acid. The whole process is more or less offensive from the presence of the organic materials, and the fumes given off during the manufacture and the subsequent drying.

" Poudrette " is generally manufactured from privy or pail contents, fish offal, etc., by treatment with sulphuric acid; it consists of a brown dry powder. The process must be conducted under very special conditions, or a grave nuisance results.

Paper making.—Cotton and linen rags, wood pulp, hemp, straw, waste paper, etc., and esparto grass are employed in this business. The rags are " dusted," and then placed in boilers to which caustic soda is added. After the rags have been well boiled, the liquid should be run into settling tanks, and subsequently filtered through earth and ashes, before it is permitted to enter a stream, so as to obviate serious pollution and nuisance. When the rags are removed from the boilers, they are washed and bleached.

Esparto grass is reduced to pulp by boiling with caustic alkali and by subsequent treatment by machinery.

The vapours given off during the boiling of the grass, and from the hot liquor after removal from the boilers, have an offensive senna-like odour, but the recovery of the soda from the waste liquor is the most offensive part of the process.

This subject of the vitiation of air in industrial occupations is further discussed in the chapter upon " Industrial Hygiene."

Household Dust.

Besides vitiation by products of respiration and combustion, one great cause of impurity of air in houses is the presence of floating particles of dust. This dust is the débris arising from the wear and tear of articles in domestic use, mingled with the soot and ashes from fireplaces, lamps, and gas-burners. As soon as the air is still it tends to settle upon walls, floors, and articles of furniture, to be again caught up and wafted into the air, when this is in brisk movement. Under the microscope this dust resolves itself into soot, mineral particles (silica, oxide of iron, crystals of sodium chloride), cotton fibres, spores of fungi or bacteria, starch grains, pulverized straw, epithelial and epidermic débris from the skin. It is thus seen to consist largely of organic refuse, sometimes more or less putrescent, and its presence in the air assists in the production of the low state of health so common to the occupants of dirty overcrowded houses.

In all houses dust must be produced by the wear and tear of domestic life; but in towns this strictly domestic dust is much augmented by that which finds its way in through doors and windows from the outer atmosphere. We cannot hope, then, to materially limit its production; but much may be done to get rid of it, and to prevent its undue accumulation, by thorough and regular house cleaning.

House cleaning can only be efficient where the structural conditions of walls, floors, and ceilings permit of easy access for the broom and duster into every part of the room, and where furniture and fittings are so arranged as to prevent dust being deposited in inaccessible places. Damp dusters should be used for "dusting."

As generally arranged, nearly every part of a room is a dust trap. Cornices and projections on ceilings and above doors; rough or flock wall-papers; floors with crevices between the boards into which dust drops, to gradually accumulate between the floor and the ceiling below; carpets accurately fitting every corner of the room; cumbersome articles of furniture, as wardrobes, sideboards, and bookcases, which collect dust above, and are too heavy to be moved to allow dust to be swept out below; heavy curtains with canopies, draperies, etc.—all these tend to the collection of dust, which, being unseen, is forgotten and not removed.

It is especially in bedrooms, which are occupied for so many

hours without any thorough renewal of the air, that these dust accumulators tend to do so much harm, by contaminating an atmosphere already vitiated. The following rules, therefore, although to be recommended in every room of a house, are more especially applicable to bedrooms.

The floors, if old and warped, should be accurately fitted with thin oak parqueterie, kept well polished with oil and beeswax; or the spaces between the boards may be filleted—*i.e.*, filled in with strips of wood, so as to leave no chinks—and the whole either stained or varnished, or coated with three or four good coats of paint and varnished. This flooring can be kept clean with a damp duster. Carpets should be abolished in favour of mats or Indian matting for bedrooms, which is very little retentive of dust and easily cleaned. The mats can be frequently shaken and beaten in the open air, whereas fixed carpets are usually beaten once a year, and in the interval accumulate much dust (especially the thick pile carpets). The use of linoleum and oilcloth should be avoided, as it hinders the ventilation of the boards, and tends to cause dry-rot.

Heavy curtains, canopies, and draperies should be replaced by light muslin fabrics in bedrooms, which can be washed and cleaned at frequent intervals. Bedroom furniture should be light and easily moved. It would be a great improvement if, when houses are built, the bedroom walls were planned with recesses, which could be converted into cupboards, shelves, and drawers; and thus the actual furniture of a bedroom could be reduced to the bed, washstand, dressing table, and chairs, and there would be no surface on which dust could lie concealed.

Cornices and projections from walls and ceilings should be avoided, as likely to collect dust.

The vacuum cleaning process has come largely into use for removing dust and deposits from rooms. A small machine outside the house, or actuated by electricity inside a house with electric supply, produces a vacuum in a chamber to which is connected a long flexible pipe. The nozzle end of this pipe is applied to all parts of and the furniture of a room to be cleaned; and the dust is drawn by suction into the receiving chamber with very little disturbance of the contents of the room. Carpets and hangings are very effectually "dusted" by this process.

The wall coverings should be smooth and glossy. Rough wall-papers, especially flock papers, can hold enormous quantities of

dust. For bedrooms and nurseries distemper colouring is perhaps better than wall-papers, as the surface can be renewed at a trifling cost and at frequent intervals. In distempering, common whiting is used as a basis for the colouring, and not white lead or zinc white, as is almost invariably the case in painting. Newly painted surfaces give off traces of lead, volatilized or in powder, to the air in drying; and symptoms of lead poisoning have frequently been observed in the occupants of a freshly painted room. Painting, then, is not to be recommended for wall surfaces, unless the paints are warranted free from lead. Sometimes the paints themselves contain no lead, but the "dryers" with which they are mixed before use are found to be full of lead.

Varnished wall-papers are coming more largely into use. They have a smooth non-absorbent surface, and are easily cleaned with a damp cloth. In papering a room it is important to see that the old paper is all peeled off, and the plaster underneath well washed, before the new paper is applied. The size and paste used should be perfectly fresh.

A paper should never be put on a wall unless it is guaranteed free from arsenic; and it is even advisable to test a piece with Marsh's apparatus to make perfectly certain. The general supposition is that wall-papers are not likely to contain arsenic unless they are coloured some shade of green. But arsenic has been found in various coloured papers—reds, mauves, browns, and greys. The arsenite of copper (Scheele's green) and the aceto-arsenite of copper were formerly principally used in the manufacture of green papers. The amount of arsenic present has been found to vary in different cases from a grain, or less, per square yard up to 50 or 60 grains; but in more recent years little more than traces have been discovered.

The injurious effects of arsenical wall-papers appear to be due to the dissemination of volatile arsenical compounds, or of solid particles of arsenious acid or even metallic arsenic, as dust, into the air of the apartment. In flock papers, coloured with arsenic, it is probably diffused as dust; whilst in the smoother papers, arseniuretted hydrogen or other volatile compounds are formed by the decomposition of the size and paste on a damp wall acting chemically on the arsenical salt.

The long-continued inhalation into the lungs or swallowing of the arsenical dust and vapours derived from wall-papers tends to produce a chronic form of poisoning, characterized by one

or more of the following symptoms, arranged more or less in the order of their appearance, viz., conjunctivitis and lacrymation, cough, nausea, sickness and diarrhœa, colic pains, cramps, dryness of the mouth and throat with much thirst, headache and gradually increasing debility, with actual paralysis of the extremities, terminating in convulsions and death.

As a rule, the symptoms do not go beyond conjunctivitis, cough, nausea, and diarrhœa, with much debility. But these cases of illness often last for a long period, until, indeed, the source of the poisoning is discovered.

VENTILATION.

Ventilation is a term which has a somewhat extensive meaning. Generally it may be said to imply the removal and dispersion of foreign gases or suspended matters, which have accumulated in the atmosphere as the result of the vitiating processes already described. We speak of the ventilation of streets and buildings, the ventilation of inhabited rooms, factories, and mines, and the ventilation of drains and sewers. In each case the same object is aimed at, but the means by which it can be attained are different. The ventilation of streets and buildings is dependent upon the width of the street, and the height of adjoining or opposite buildings—in fact, upon the amount of free air space around the buildings, and the facilities afforded for the entrance of light and air; this may be called "external ventilation." To ventilate dwelling houses, factories, or mines, fresh air from outside must be introduced within these more or less closed places by natural or artificial means, and adequate exit must be provided for used or vitiated air. It is the same for drains and sewers, with this addition, that the escaping air must be allowed exit at points where it is least likely to be productive of nuisance or danger. In addition to the natural forces of rain, wind, sun, and vegetation, which promote the purification of the atmosphere on the large scale, *natural ventilation* as applied to circumscribed localities may be said to depend upon (1) *diffusion of gases*; (2) *the action of the winds*; (3) *the difference in weight of masses of air of unequal temperature.*

1. Gases diffuse inversely as the square roots of their densities; and this diffusion can take place through porous substances such as dry bricks. The process is necessarily a

slow one, and inadequate to produce complete renovation of vitiated air.

2. Winds are very powerful ventilating agents. They act chiefly by *perflation*, *i.e.*, by setting masses of air in motion, driving them onward by propulsion. They have also an *aspirating* effect on air which is shielded from the direct or perflating action. For when wind passes horizontally over chimneys, or tubes placed at right angles to its course, it causes a diminution of pressure within them, thus creating a current of air up the chimney. The air in these tubes being partially aspirated or sucked out by the action of the wind, to restore the temporary vacuum so made, air from below rushes up to take its place, a continuous current in a perpendicular direction being thus set up.

3. When air is heated it expands. The expansion is equal to $\frac{1}{273}$ of its volume at 0°C for every degree Centigrade. A volume of hot air is consequently lighter, bulk for bulk, than the same volume of colder air. The warm air rises, and equilibrium is restored by colder air rushing in to occupy its place. The winds themselves are caused in this manner by the unequal heating of the air over different parts of the earth's surface.

External Ventilation (Around Buildings).

The health of a town largely depends on the width of its streets, the general height of the buildings, and the amount of yard space at the rear of each building which separates it from its opposite neighbour. Contrast the health and vitality of the occupants of houses in wide open streets with those who live in narrow courts closed at one or both ends, the courts themselves being surrounded by high buildings, or built back to back, or with the smallest possible intervening space. In such places the air is almost always necessarily stagnant, as the passage of the wind is obstructed by the surrounding buildings. The sun's light—the most powerful of germicides—for many months in the year cannot penetrate, with the result that the ground is never thoroughly dried, and the air in contact with it remains continuously damp. Impure gases and exhalations, evolved from the inhabited dwellings, are not at once swept away by the wind, and consequently accumulate in the air of the court and its surroundings. Suspended organic matters tend to accumulate in the still air, which, being thus both damp and impure, produces

that state of low vitality and predisposition to disease which characterizes the inhabitants of such places.

Absence of sunlight appears to have a specially injurious effect on child life, which, like plants, becomes blanched and weakly when reared in semi-darkness, and it tends to the production of rickets. When it is added that in many of these courts and alleys the houses have no through ventilation, the windows being only in front of the house, it is not to be wondered at that the general death-rate is sometimes double, or even treble, that of the healthy parts of the town, and that the mortality amongst infants and young children is heavy. All investigations into the effect of back-to-back houses upon the health of the inmates show an increased incidence of disease and mortality from all causes, phthisis, diseases of the respiratory organs, diarrhœa, and zymotic diseases generally; and in districts where such houses form about 50 per cent. of the total, the death-rates from the above-mentioned causes are nearly half as much again as the rates generally prevailing for the whole of England and Wales. Back-to-back houses are built in double rows with only one side exposed to the open air, except in the case of those houses at the ends of the blocks, which have two sides open to the external air. Through ventilation is impossible in such houses, and the rooms are generally dark and dirty as a consequence.

To indicate what is the minimum amount of external air-space which should be allotted to every building in a town, we may quote from the model bye-laws of the Local Government Board and the London Building Act, 1894, which refer to new streets and buildings.

The width of every street intended for use as a carriage road must not be less than 36 feet; if not to be used as a carriage road it must be at least 24 feet wide, and open at one end. Twenty-four feet is the least width allowed before the frontage of any new building; and the aggregate amount of yard space at the back of such a building, and belonging to it, must not be less than 150 square feet, and, whilst extending the entire width of the building, it must not in any case be less than 10 feet wide, and must be wider when the height of the building exceeds 15 feet.

It is important to note that the model bye-laws insist on the yard space at the back of a house being increased with the height of the house up to 35 feet, but not so the frontage area. The higher the buildings, of course, the greater the obstruction to the passage of air and light, and the amount of space compulsorily left unoccupied (both in front and back) should have been correspondingly increased.

The erection in London and some large provincial towns of huge blocks of industrial dwellings, whilst affording vastly superior accommodation to the working classes over the old insanitary tenements, has not always secured efficient external ventilation for certain of the tenements. Lofty blocks are too often built in such a way as to enclose a narrow and well-like court, in which the atmosphere is always sunless and stagnant, and from which the rooms facing on to it derive all their light and air. Cottage buildings with sufficient space in front and rear are far preferable to lofty blocks placed in rows; but as they do not house the same number of people for the space occupied, in crowded districts, where the land is of such enormous value, the rents must necessarily be higher.

The London Building Act, 1894, Part V., provides for open spaces about buildings and the height of buildings. It requires to be provided in the rear of every such building an open space exclusively belonging to it of an aggregate extent of not less than 150 square feet, the open space to extend throughout the entire width to a depth of at least 10 feet from the building. The height of the building is regulated as follows: An imaginary horizontal line is drawn at the level of the pavement from the roadway, and at right angles to it through the centre of the face of the building, and prolonged to intersect the boundary of the open space at the rear. An imaginary diagonal line is then drawn in the direction of the building above, and in the same vertical plane with the horizontal line, and inclined thereto at an angle of 63·5°, meeting the horizontal line where it intersects the boundary of the open space at the rear. No part of the building will then be allowed to extend above the diagonal line, except chimneys, dormers, gables, turrets, or other architectural ornaments. Exception is made in the case of new buildings abutting at the back upon a street or open space dedicated to the public.

With respect to new domestic buildings abutting upon a street formed or laid out before the commencement of the Act, the horizontal line may be drawn at a level of 16 feet above the level of the adjoining pavement, and the open space of 150 square feet may also be provided above the level of the ceiling of the ground story, or 16 feet above the level of the adjoining pavement.

Section 45 prohibits the construction of habitable rooms lighted and ventilated entirely from enclosed courtyards, or from courtyards open on one side, but of which the depth, measured from the open side, exceeds twice the width, unless the width of the court measured from the window of the room to the opposite wall is equal to half the height measured from the sill of the window to the eaves or top of the parapet of the opposite wall.

Section 47 enacts that a building (not being a church or chapel) shall not be erected of or be subsequently increased to a greater height than 80 feet (exclusive of two stories in the roof, and of ornamental towers, turrets, or other architectural features) without the consent of the Council; provided that where any existing buildings forming part of a continuous block or row of buildings exceed 80 feet in height, any other building in the same block belonging to the same owner at the date of the passing of the Act may be carried to a height equal to, but not exceeding, that of the existing buildings.

Section 49 requires that no existing building (other than a church or chapel) on the side of a street formed or laid out after August 7, 1862, and of a less width than 50 feet, shall be raised, nor shall any building be erected so that the height of the building exceeds the width of the street, without the consent of the Council.

Smoke Prevention.

The securing of a national economic use of coal and the prevention of smoke are one and the same problem. The waste of coal fouls the earth with ashes and soot, the sky with smoke, destroys beauty, dirties houses, makes cities dismal, causes vast expenditure in cleaning, painting, rehanging, and furnishing. Fog caused by smoke wastes artificial light, and, by impeding transport of people and goods, interferes greatly with the conduct of business and manufacture. The material damage done by smoke to property in Manchester and Salford has been estimated at one million pounds a year, or about one pound per head of population; and it has been shown by Prof. J. B. Cohen and Mr. A. G. Ruston, of the University of Leeds, that the pall of smoke which continually hangs over that city absorbs as much as 40 per cent. of the total daylight during the year. It is to this continual reduction in the available sunlight that the more insidious and serious effects of smoke upon human vitality and vegetable growth must be attributed.

In London the smoky atmosphere of the winter months is almost entirely due to the unconsumed smoke from private dwelling houses, whilst in the Northern towns it is the manufactory smoke that pollutes the air, a fact at once evident from the very striking contrast between the air on Sundays and the dense smoke cloud that overhangs the town on the working weekdays. To deal with the whole smoke question in London is to attack a problem of unexampled magnitude and difficulty; all that can be hoped for is that coal gas may in time be so far cheapened as to replace with economy the common use of coal for domestic heating and cooking purposes.

A Departmental Committee (1920) arrived at the conclusion that even in industrial areas domestic chimneys contribute at least 50 per cent. of the total smoke nuisance, and that at least 6 per cent. (amounting to two and a half million tons annually) of bituminous coal burnt in domestic fireplaces escapes unconsumed into the atmosphere. Domestic soot contains a higher percentage of tar than factory soot, and is therefore more destructive.

In the Lancashire and Yorkshire towns the abatement of smoke is a far easier task to accomplish, and already a good deal has been done in this direction by the adoption of smoke-preventing appliances in connection with factory furnaces. The smoke nuisance is chiefly due to the fireman allowing too long intervals between the firings. This leads to too much coal being put on at one firing, and the issue of black smoke; but a deficient air draught—often due to a small cramped flue in a low chimney—is frequently a cause. The best method of smoke prevention is to secure frequent and light firing, and the admittance to the furnace of the necessary air to provide complete combustion of the carbon particles after each fresh charge of fuel. Many devices are employed to secure these objects independently of the fireman. Of these appliances, perhaps the most commonly used are the mechanical stokers, which may conveniently be divided into two classes: (*a*) Those that throw small quantities of fuel evenly over the fire, and thus obviate the dense black smoke produced, under the ordinary conditions of stoking, when the fire door is opened and fresh fuel is cast by a fireman on the fire. It is evident that with stokers of this class ("sprinklers") the fire bars must be made to move by appropriate mechanical arrangements, and so keep the fire level and free from aggregations of imperfectly coked fuel at certain parts of the furnace.

The second class of mechanical stokers (*b*) are those of the coking class. By these the fresh fuel is delivered from a hopper to the front of the fire, where it gets coked; it is then gradually worked backwards on the fire bars, until the clinker falls over the back of the grate into the ashpit. By these contrivances the furnace is continuously taking in the raw fuel at the front, burning this smokelessly (because the black smoke arising at the front of the furnace is "killed" by passing over the white hot fuel at the back), and dropping the ashes over the other end of the bar. "Side firing" is said to give good results. By this method the fuel is delivered at each side of the fire alternately, and the smoke from the side which is being fed curls towards the incandescent fire on the other side, and gets burned. These coking mechanical stokers give far better results than the sprinkling class.

As smoke arises from a furnace when the supply of air admitted is inadequate to secure complete combustion of the fuel, a great number of contrivances have been invented for supplying air, either heated by passing through special pipes laid in the flues,

or cold, to various parts of the furnace or main flue. Grids or circulars which can be opened and shut by hand are sometimes placed in the door to admit air to the furnace, and panels and louvres in the furnace door are now made to open and shut automatically. These can be regulated to admit the desired quantity of air. "Forced draughts" are often utilized to increase the draught in the furnace, and thus to favour combustion, and for this purpose jets of steam are generally admitted through the frame of the furnace just above the door. Again, split bridges or hollow fire bars of various kinds are made to admit air. The "bridge" is the metal or brickwork projection at the back of the fire bars, over which the flames and products of combustion pass on their way to the flue. There is a door underneath the split bridge, which can be opened, when firing is taking place, to let the air pass up through the bridge to ignite the gases passing over it and further complete combustion. Split bridges may be made to work automatically, and many are in use; but if left continually open, they tend to destroy the draught in the front part of the furnace, and they soon get filled with ashes.

Revolving cast-iron chain grates are now being used in certain classes of furnace in connection with mechanical stokers. The revolving grate carries the incandescent fuel slowly from the front to the back of the furnace, where the spent fuel falls into the ashpit. These grates are intended for consuming soft coal, and not Welsh steam coal, the excessive heat from the latter being too speedily destructive of the cast-iron chains.

Amongst less effective appliances may be mentioned the use of fans to force the smoke again through the furnace, and the washing of the smoke by passing it through shafts in which sprays of water are descending.

There is a considerable advantage to the manufacturers in the use of mechanical stokers, inasmuch as they can by their means burn an inferior slack coal (cheaper fuel), and less labour is required. If split bridges only are used, great care is required on the part of the fireman, and fuel of fair quality must be used, or smoke is emitted; whilst the mechanical stokers do away with these sources of expense.

In conclusion, it may be said that the quality of the coal used has an important bearing on the subject of smoke prevention, and that coke and anthracite are practically smokeless. The ordinary or bituminous coal is much cheaper, weight for weight,

than anthracite, but on account of the greater heat obtained from the latter it is said to be almost as cheap in use. Coal-dust firing is held by a recent Prussian Commission to possess the following advantages: It allows of uniform distribution; it permits of perfect combustion without smoke; and secures the greatest calorific efficiency.

The Public Health Act, 1875, defines as a nuisance "any fireplace or furnace which does not as far as practicable consume the smoke arising from the combustible used therein, . . . and which is used in any manufacturing or trade process whatsoever." It should be noted that when any chimney (not being the chimney of a private dwelling house) is sending forth *black smoke* in such quantity as to be a nuisance, it is not necessary to prove, in order to secure a conviction, that the furnace is improperly constructed or inefficiently tended.

The London County Council is of opinion that the escape of black smoke for five minutes from the lighting of the furnace might be permitted, but that afterwards a discharge of one minute or more should be the subject of legal procedure. The allowance varies from two to fifteen minutes in other large towns.

In Sheffield the following working limits must not be exceeded:—

1 boiler ..	.. 2 minutes of black smoke in the hour.
2 boilers ..	.. 3 ,, ,, ,, ,,
3 ,, ..	.. 4 ,, ,, ,, ,,
4 ,, and more	.. 6 ,, ,, ,, ,,

Ventilation of Inhabited Rooms.

Fresh air refreshes by its rapid removal of heat from the body; and *the prime requirement of ventilation is to keep the air relatively cool and in gentle motion*. The problem is one of maintaining air-freshness rather than air-*purity*; for the beneficial results of fresh air are chiefly on the surface of the body and not on the lungs. The bracing effect of the ceaseless flow of sensory impressions resulting from the movement of cool air over the skin is also of high value in promoting our efficiency; we live on a higher plane, and all our vital functions are "toned up." Thus fresh air promotes the vigorous tone of the nervous system; favours the circulation and the best distribution of the blood in the system; more oxygen and food are taken in, and metabolism is increased; it tones up the system and makes us more vigorous of brain and

muscle; while warm, foul air relaxes and enervates, and lowers our efficiency. It is not surprising, therefore, that the sedentary worker in unduly warm and insufficiently ventilated offices, work-rooms, and sitting-rooms suffers a loss in bodily and mental vigour. It is the penalty that he pays for his neglect of fresh air and exercise. The aim of ventilation should be to produce an atmosphere cool rather than hot, dry rather than damp, diverse in temperature rather than uniform and monotonous, and moving rather than still.

In providing for the ventilation of inhabited rooms by the replacement of vitiated air by fresh air, a certain standard of impurity was formerly adopted above which no increase should be allowed.

Pettenkofer proposed as a standard for inhabited rooms 1 volume of CO_2 per 1,000 of air. Carnelly, Anderson, and Haldane proposed 1·3 per 1,000 for elementary schools during the daytime, and 1 per 1,000 for dormitories at night. The only legal maximum standard at present in force is that fixed by the Home Office in respect of cotton-cloth factories, where the air requires to be humidified by the addition of steam, namely 0·9 vols. of CO_2 per 1,000.

It was found by the late Professor De Chaumont, by chemical examination of a large number of samples of the air of inhabited rooms, that—the amount of CO_2 in the outer air being 0·04 per cent., or 0·4 per 1,000—no close or disagreeable smell is perceived in the air of a room until the CO_2 from human respiration reaches 0·6 per 1,000, or exceeds by 0·2 per 1,000 that present in outer air, the close smell being always due to the foul organic matter in the impure air, which generally increases *pari passu* with the amount of CO_2 present. When the CO_2 in an inhabited room reaches 1·3 per 1,000, the limit of appreciation of stuffiness, when a person first enters such a room from the outer air, is reached. It was assumed by De Chaumont that air vitiated to the extent of 0·2 per 1,000—air which is still fresh and does not differ sensibly to smell from the outer atmosphere—can be breathed with impunity, but that no greater vitiation ought to be allowed. The permissible limit of respiratory impurity was therefore held to be 0·2 per 1,000 (which is the same thing as 0·0002 cubic foot of CO_2 per 1 cubic foot of air).

By the equation $D = \frac{E}{r}$—(where E = amount of CO_2 exhaled,

r = respiratory impurity per cubic foot of air, and D = the delivery, or the amount of fresh air available in cubic feet) if E and r are known we can find D, or if D and E are known we can find r. If $E = 0{\cdot}6$,[1] and $r = 0{\cdot}0002$, then $D = \frac{0{\cdot}6}{0{\cdot}0002} = 3{,}000$. That is to say, each individual requires by this standard, 3,000 cubic feet of fresh air per hour in order that the respiratory impurity may not exceed 0·2 per 1,000.

In a similar way it can be shown that when the adult male is doing gentle work (and giving off 0·9 cubic foot of CO_2 in the hour) he theoretically requires 4,500 cubic feet of fresh air per hour; and if he is engaged in very hard work (and giving off, maybe, 1·8 cubic feet of CO_2 per hour) he needs as much as 9,000.

Example 1.—If a room of 1,000 cubic feet is occupied for four hours by 10 persons, each giving off the average amount of CO_2, what will be the total amount of CO_2 per 1,000 volumes at the end of the time, supposing 10,000 cubic feet of fresh air per hour have been supplied ?

In this problem D and E are given, and we have to find r. The total amount of air available for breathing by the 10 persons in the four hours is 1,000 cubic feet (the cubic space of the room) + 10,000 × 4 (the amount in cubic feet supplied in four hours) = 41,000 cubic feet = D. The amount of CO_2 expired by 10 persons in 4 hours $= 0{\cdot}6 \times 10 \times 4 = 24$ cubic feet = E.

$$D = \frac{E}{r} \text{ or } r = \frac{E}{D} = \frac{24}{41{,}000} = 0{\cdot}00058 \text{ per unit;}$$

i.e., r, or the respiratory impurity, is 0·58 part per 1,000. The total amount of CO_2 in the air will be $0{\cdot}58 + 0{\cdot}4 = 0{\cdot}98$ part per 1,000.

Example 2.—The air of a room occupied by 6 persons, and containing 5,000 cubic feet of space, yields 7·5 parts of CO_2 per 10,000 parts. How much air is being supplied per person per hour ?

Here E and r are given, and we have to find D. $E = 0{\cdot}6 \times 6 = 3{\cdot}6$ cubic feet CO_2 exhaled in 1 hour. $r = 7{\cdot}5 - 4 = 3{\cdot}5$ per 10,000, or 0·35 per 1,000, or 0·00035 part of CO_2 per cubic foot.

$$D = \frac{3{\cdot}6}{0{\cdot}00035} = 10{,}285.$$

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[1] A man at rest inspires and expires about 17 times a minute; at each inspiration about 30 cubic inches of air are taken into the lungs and subsequently expired. The cubic feet of air inspired and expired in one hour will be $\frac{17 \times 30 \times 60}{1728} = 17{\cdot}6$. As the CO_2 gas in air expired from the lungs amounts on the average to 4 per cent. by volume, the amount of CO_2 given off in an hour will be $\frac{4}{100} \times 17{\cdot}6 = 0{\cdot}7$ cubic foot. For a mixed population of men, women, and children, the amount of CO_2 is generally taken as 0·6 cubic foot per head.

But the room contains 5,000 cubic feet of space; therefore in the first hour 5,285 cubic feet of fresh air were supplied, or 880 cubic feet per head. After the first hour, to maintain the same amount of CO_2 in the air, the full 10,285 cubic feet of fresh air will have to be supplied, or 1,714 cubic feet of fresh air per head per hour.

During exertion a man gives off more respiratory impurities (CO_2, organic matters, etc.) than when at rest. For this reason, and also because the air is generally further vitiated by the trade process, the amount of air supplied to factories or work-rooms should exceed—the excess varying with the nature of the work—that required in an ordinary living or sleeping apartment. Some allowance, too, must be made for lights, especially gaslights, when the products of combustion are allowed to escape into the air of the room.

The amount of *cubic space* allotted to each person in a room is a matter of great importance, not because cubic space, however large in amount (as met with under ordinary conditions of inhabited dwellings), can take the place of a regular supply of fresh air from outside, but because the larger the cubic space the easier it is to supply the proper amount of air without creating a draught. For instance, suppose in a dormitory occupied by ten persons the amount of space per head is only 300 cubic feet, to supply 3,000 cubic feet of fresh air per head per hour 30,000 cubic feet must be admitted in this period, and the air of the room will have to be completely changed ten times—a proceeding which would cause in cold weather, unless the entering air was warmed, a most disagreeable draught. But if the cubic space per head be 1,000 cubic feet, then the air of the dormitory need be changed only three times per hour; and if such renewal is effected steadily and gradually, the cold entering air is at a low velocity, and, mixing with the warmer air of the compartment, creates no draught.

A certain amount of *superficial* or *floor space* is necessary for each individual, for if the height of the room is much over 12 feet, excess in this direction does not compensate for deficiency in the other dimensions, although the total cubic space may be the same; thus, it would not be the same thing to allow a man 50 square feet of floor space in a room 20 feet high as to provide 100 square feet in a room 10 feet high, although the cubic space would be identical. The reason is that the products of respiration are not readily diffused throughout the air of an apartment.

but tend to accumulate in the lower strata, consequently excessive height does not, in their case, mean a corresponding dilution.

Haldane and Osborn in their examination of the air of factories and workshops found that some of the rooms, where there was the largest amount of cubic space per head, contained the foulest atmospheres, there being no proper means of ventilation, the air never being thoroughly renewed, even when the rooms were empty.

The cubic and superficial space allotted under various statutes, bye-laws, and regulations are given below:

	Minimum Space per Head in Cubic Feet.	Authority.
Common lodging houses (sleeping rooms)	300	Local Government Board (Model Bye-laws).
Registered lodging houses—		
Rooms occupied by day and night	400	Ditto Ditto
Rooms occupied by night only	300	Ditto Ditto
Non-textile workrooms ..	250	Factory Act, 1901.
Non-textile workrooms during overtime	400	Ditto Ditto
Underground bakehouses ..	500	Order under Factory Act, 1901.
Above ground bakehouses where night work is carried on by artificial light other than electric light	400 c.ft. between 9 p.m. and 6 a.m.	Ditto Ditto
Army barracks	600	British Army Regulations.
Army hospital wards	1,200	Ditto Ditto
Public elementary schools ..	80[1]	Education Department.
London County Council schools	130[2]	London County Council.
Canal boats (persons over 12 years)	60[3]	Local Government Board Regulations under the Canal Boats Act, 1877.
Canal boats (persons under 12 years)	40[3]	
Seamen's cabins	120	Merchant Shipping Act, 1906.
Cows in cowsheds	800	Local Government Board. Model Regulations under the Dairies, Cowsheds, and Milkshops Order.

[1] Minimum floor space 8 square feet.
[2] Minimum floor space 10 square feet.
[3] An after-cabin must not be less than 180 cubic feet in capacity nor a forecabin less than 80.

In the large public schools of this country the amount of superficial area and cubic space varies according to the ages of the boys and other circumstances. Average requirements for boys of 12-18 years of age are 70-80 square feet of floor space and 700 to 900 cubic feet of air space; but, as previously pointed out, ample floor and cubic space will not compensate for defective ventilation. Unhealthy conditions of atmosphere are sometimes found to prevail in large and lofty dormitories, where defective ventilation leads to stagnation of air.

The reader must realize that the above-mentioned standard of 3,000 cubic feet of fresh air per head per hour is based upon De Chaumont's conclusion that the respiratory impurity in terms of carbonic acid should not rise above 0·2 per 1,000, and that this carbonic acid limit was adopted not on account of any danger from the increased carbonic acid, but because he found that when it was exceeded a faint stuffiness of the atmosphere became appreciable. But such stuffiness of the atmosphere mainly results from dirty bodies, and later experiments by Kenwood have shown that in many workrooms and in senior classrooms of elementary schools, stuffiness is rarely appreciable until the respiratory carbonic acid reaches or exceeds 0·3 per 1,000. If this latter figure were accepted, the result would be that the supply of fresh air per head per hour would be reduced to 2,000 cubic feet—an amount which is far more practicable than the 3,000 standard. There is, moreover, evidence that a 2,000 cubic feet standard of fresh air per hour would not only suffice to prevent stuffiness in almost all cases, but that the physical state (temperature and humidity) of the atmosphere would continue to be satisfactory.

Although, then, the amount of respiratory CO_2 in the air (within any likely degree of "overcrowding") does not matter, it remains a useful index to bad air conditions; for although a low figure of respiratory CO_2 does not, *per se*, guarantee a satisfactory atmosphere, the harmful physical changes increase pretty much *pari passu* with the respiratory CO_2.

During the colder months of the year in this country three complete changes per hour of the air in an inhabited room is all that can be borne when the entering air is not artificially warmed. Hence the importance of an allowance for each individual of cubic space not much less than 1,000 cubic feet. The area of the inlet opening should be sufficiently large to allow the required volume of air (3,000 cubic feet) to enter at no greater speed than 5 feet

per second. This can be attained where the inlet opening for each individual is 24 square inches. A velocity of the entering air of 2 to 3 feet per second is far more agreeable to the senses than a velocity of 5 feet. If the entering air is artificially warmed, the size of the inlet opening may even be increased up to 70 or 80 square inches per head, and the amount of cubic space may be diminished, for it would be possible then to change the air of the apartment more frequently than three times per hour without creating a draught. During the colder weather a current of air striking an individual will not generally be tolerated if it exceeds a velocity of ½ a foot per second at a temperature of 60° to 65° F., or 1 foot per second at a temperature of 65° to 70° F.; and it may be said generally that efficient ventilation is difficult to procure in cold weather, unless the entering air is artificially warmed.

Natural Ventilation.—Of the forces which act in natural ventilation, diffusion causes the gaseous impurities of respired air to mix with the fresh air in a room until homogeneity is established. Diffusion, however, does not affect the suspended matters, which tend to fall towards the earth in a still atmosphere.

The perflating action of the wind may be utilized by opening windows facing the wind, and the action is increased when windows, or a window and door, on opposite sides of a room are left open. The room is rapidly and continuously flushed with air, an enormous effect being produced, for it is possible to renew the air of a room in this manner over a hundred times an hour, even when the movement of the wind outside is only 3 feet per second, equivalent to a very gentle breeze. Such a method is of unquestionable utility for rapidly changing the air of an unoccupied room—especially school and work rooms—and may be generally put in operation in inhabited rooms in summer when the temperatures outside and inside the house approximate.

In any system of ventilation, however, that depends entirely on the wind, there is always the difficulty of regulating the velocity of the current, and during complete calms the action is of course nil. The wind, too, often impedes ventilation by obstructing the passage of vitiated air from an exit shaft into whose mouth it blows; and this is not to be wondered at, for when blowing at the rate of 10 miles an hour the pressure of the wind is ½ pound on each square foot of surface.

For ventilating the holds and cabins of ships at sea, the wind may be most advantageously utilized, because the ship's motion is almost always producing a breeze. A large cowl, placed so as to face the wind, conducts the air below by means of a pipe, whilst another cowl, reversed so as to back to the wind, allows the used air to escape. By this exit shaft the aspirating force of the wind is utilized. Sylvester's system of house ventilation proceeds on these principles. A large cowl facing the wind is placed outside the house, and conducts the air to an underground chamber, where it can be warmed if necessary by passing over hot water or steam pipes; it is then conducted to the rooms above by means of tubes, and finally escapes above the roof through tubes surmounted by cowls backed to the wind.

The aspirating action of the wind is constantly being used to ventilate rooms by means of the chimney. With a fire burning in the grate, the draught up the chimney is increased by the aspiration of the wind when the top of the chimney is above surrounding buildings. Even when there is no fire in the grate, it will usually be found that there is a current setting up the chimney. Should the top of the chimney be lower than surrounding structures, the wind striking these and then descending will often cause a back-draught and a smoky chimney. The remedy is evidently to carry up the chimney to at least the height of the surrounding buildings. A suitable cowl surmounting the chimney may prevent or mitigate back-draught. From experiments carried out by the Royal Sanitary Institute it appears that certain forms of cowls or terminals have the effect of increasing the up-draught in air shafts, but that some 30 per cent. of those forms experimented with were valueless for that purpose. It is evident that on dull days, when the atmosphere is still, ventilation is most required, and that then such air shafts surmounted by cowls or terminals are of little value. Another cause of smoky chimneys is an insufficient supply of air to the room. To feed the fire, air is drawn down the chimney, and coming down in puffs, it causes an escape of smoke. The remedy is obtained by making a suitable inlet for fresh air into the apartment.

Sometimes it is found that the smoke escaping from one chimney is drawn down another opening close by and on the same level. In such a case one of the chimneys should be raised.

The movement produced by inequality in density or weight of contiguous masses of air at different temperatures is the natural force chiefly relied on for ventilating the interior of houses in this climate. This force is naturally chiefly called into action in cold weather, when the difference between the internal and external temperature is considerable, and is more or less in abeyance in summer, when the temperature outside is often equal to, or even greater than, that of the house. The greater this difference of temperature and the difference of level between the aperture for the entrance of cold air and the aperture for the exit of heated air, the greater will be the velocity of the entering air. We are enabled to calculate the theoretical velocity by means of Montgolfier's formula, which is founded on the dynamical law that the velocity in feet per second of falling bodies is equal to eight times the square root of the height through which they have fallen. In this case the height fallen is represented by the difference in pressure of the air inside and outside the house, which is equal to the difference of level between the apertures of entrance and exit multiplied by the expansion of air caused by the difference in temperature inside and outside.

$$v = 8\sqrt{\frac{(h-h')\,(t-t')}{491^*}} = \text{velocity in feet per second,}$$

where $h =$ height in feet of aperture of exit from ground;
,, $h' =$,, ,, entrance from ground;
,, $t =$ temperature of air inside in degrees Fahr.;
,, $t' =$,, ,, outside in degrees Fahr.

In practice an allowance for friction of $\frac{1}{4}$ or $\frac{1}{2}$ must often be made. As it is impossible to tell, with any degree of accuracy, what allowance must be made for friction in any given instance, the formula is little employed in actual practice, and the anemometer (*v.* page 272) is preferred. If the area of the inlet opening is known, the amount of air entering the room in a minute or an hour can easily be calculated by multiplying the velocity of the entering air by the area of the inlet expressed as square feet, the result being the number of cubic feet entering.

In a room as usually constructed with sash windows and with a fireplace and chimney, but without any special means of venti-

* This figure represents the coefficient of expansion of the air when warmed, viz., $\frac{1}{491}$ of its volume for each degree Fahr.

lation, when a fire is burning in the grate the fresh air entering the room gets warmed as it approaches the fire, and part ascends the chimney flue while part rises to the ceiling. Cold air from outside will then enter—if the windows are closed—under the door, under the skirting boards, between the sashes of the window, and through any other chinks or apertures due to loose fittings. The bricks and plaster of the walls are also porous to a certain extent, and if uncovered by paint or wall-paper will admit a small quantity of air. Thus a large volume of air may be entering a room in cold weather when the fire is burning, although there are no visible inlets; and the amount of air thus supplied may be sufficient for the needs of two or three persons if it were properly distributed. But such is not the case. The cold air, which enters chiefly near the floor, takes as straight a course as possible to the fireplace, often producing a disagreeable draught to the feet of the occupants, whilst the heated and vitiated air near the ceiling is left unaffected.

In this country, to prevent draughts and to insure a thorough distribution, fresh air not previously warmed should be admitted into the room slightly above the heads of the occupants, an upward direction being given to it so that in rising it may lose its velocity, mix with and be warmed by the heated air in this situation, fall gently into all parts of the room, and be gradually removed by means of the chimney flue, or other outlet—which should preferably be at the highest part of the room.

The incoming air should enter a room at the height of about 5 feet, and the inlet provision should admit of being easily cleaned.

Amongst simple contrivances for windows by which these objects may be attained may be mentioned Hinckes-Bird's method (fig. 30), now so well known, of placing a solid block of wood under the entire length of the lower sash frame of a window, so as to raise the top rail of the lower sash above the bottom rail of the upper sash. By this means the air is admitted between the two sashes above the heads of the occupants of the room, and is given an upward direction towards the ceiling. The same result may be more conveniently obtained by the use of a deep beaded sill, which permits the lower sash to be raised without any passage of air under it, at the same time allowing air to enter between the two sashes. Holes bored in a perpendicular direction in the bottom rail of the upper sash, louvred panes to

replace one of the squares of glass, an arrangement for allowing one of the squares of glass, provided with side checks, to fall inwards upon its lower border, or a double pane of glass in one square, open at the bottom outside, and at the top inside, all effect the same purpose and are simple and inexpensive contrivances. Cooper's ventilator, which consists of a series of apertures in the glass of a window pane, arranged in a circle and

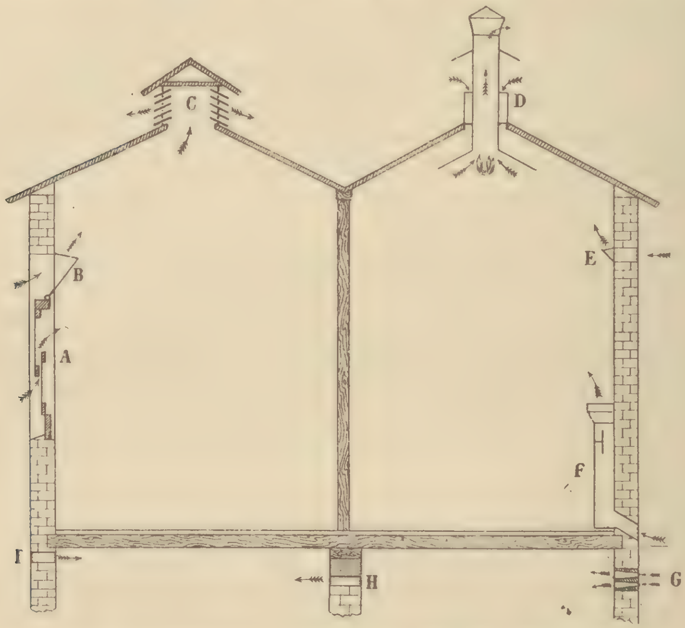


FIG. 30.—DIAGRAMMATIC SKETCH OF VARIOUS PROVISIONS FOR VENTILATION.

A, Sash window with Hinckes-Bird's arrangement. B, Hopper sash-light falling inwards. C, Louvred outlets. D, Mackinnel's ventilator. E, Sheringham's Valve. F, Tobin's Tube (showing valve open). G, Ellison's Conical Bricks. H and I, Grid ventilators below floor joists.

capable of being more or less completely closed by a circular glass disc, also with apertures, and movable on a central pivot, does not admit the air in an upward direction, but breaks it up into a number of divided currents, and thus lessens the tendency to draught. The same object can be obtained by placing wire gauze or muslin over any inlet opening.

A very useful form of window ventilator is that known as the "hopper inlet." A glazed frame, the same width as the window,

and about 18 inches deep, is fixed to the lower sill by its lower border, and is made to fall inward, moving in a frame which has side checks to obviate lateral movements of air. When the lower sash is raised, air enters, and is deflected upwards in a slanting direction by the glazed hopper. When the window is shut, the hopper is pushed up so as to be parallel with the sash, and, being glazed, there is no loss of light. These hopper inlets are found to be very useful where radiators are fixed on an external wall under a window, as they allow cool air to pass in and mix with the heated column of air rising from the radiator.

Hopper inlets are also used above the sash frame of a window. Here the air is admitted nearer the level of the ceiling, and cold draughts may be experienced, owing to the air descending before it has become mixed and warmed with the air of the apartment. The hoppers should be glazed and provided with side checks. They are often used in hospitals and other institutional buildings, where it is undesirable to have inlets nearer the floor, owing to beds or seats near the external walls.

The most generally used wall inlet ventilators are Sheringham's valve, Tobin's tube, and Ellison's conical bricks.

In the Sheringham valve (fig. 30) air passes through the wall by means of a perforated iron plate, and is then directed upwards by a valved plate with side checks, which projects into the room, and, being hinged at its lower border, is capable of being more or less completely closed by a balance weight. The usual size of the inlet opening in these ventilators is 9 inches by 3, giving an area of 27 square inches.

In Tobin's tube (fig. 30) air is introduced from the outside at the floor level through a perforated plate, and then passes up a vertical tube to a height of from 4 to 6 feet above the floor. After escaping from the tube, the current of air ascends more or less vertically for a short distance, before it begins to spread out and mix with the air of the room. In these two contrivances (Tobin's tube and the Sheringham valve) the entering air may be filtered through muslin or cotton-wool, or made to impinge upon a tray containing water, and so deposit its sooty particles—a procedure often advisable in smoky towns, but one which seriously reduces the air supply.

Tobin's tubes and other inlet and outlet ventilators should be made accessible in all their parts for cleansing, as they quickly become lined internally with dirt and adherent filth. Tobin's

tubes should be made detachable from the external wall opening for this purpose.

Ellison's bricks (fig. 30) are pierced with conical holes, the small opening, $\frac{1}{5}$ inch in diameter, being placed outside the building, whilst the larger opening, $1\frac{1}{4}$ inches in diameter, is placed inside. The thickness of the brick is $4\frac{1}{2}$ inches. The air passing through these conical apertures becomes distributed over a gradually increasing area, and in this way its slow entrance is rendered imperceptible and unproductive of draught. These bricks may be used for ventilating drill-halls, gymnasia, stables, and cowsheds.

All the inlet ventilators described are intended to utilize the movements produced by contiguous masses of air at unequal temperatures. For this reason they should be protected as far as possible from the perflating action of the wind. This cannot, however, always be done; and when a strong cold wind is blowing into a ventilator, even of the most approved sort, a most unbearable draught may be the result. To obviate this, there should be some means of controlling the amount of entering air by partially closing the ventilator, and in many cases the ventilator must be closed altogether. Sheringham's valve, Tobin's tube, and louvred inlets, fulfil these requirements very satisfactorily. It is often found that inlet ventilators are acting as outlets for the escape of air, when fresh air is entering a room from other sources. This cannot be obviated, nor, indeed, is it necessary. All that can be done is to place the inlets in the best possible position for distributing the entering air throughout the apartment without causing a draught, and to close up all such sources of entering air as are productive of draughts.

The usual outlet for the vitiated air of a room is the chimney flue; and this, for an ordinary medium-sized sitting-room, with a fire burning in the grate, is sufficient for three or four people provided no gas is alight, or the gas lamp has its own special ventilating arrangement. With an ordinary fire, from 10,000 to 15,000 cubic feet of air are drawn up the chimney in an hour, the current being generally from 3 to 6 feet per second; but a large fire will often induce a current of 8 or 9 feet per second.

Heated air rises to the top of a room; therefore the proper place to admit of the vitiated air escaping is in or near the ceiling.

Neil Arnott's or Boyle's valves, in which a metal frame supports small talc plates, which open into the chimney flue near the ceiling, are sometimes used as outlets for foul air. They permit air to

pass from the room into the flue, but the talc plates prevent its return; the objections to their use are that they occasionally permit the reflux of smoke into the room, and the movements of the plates produce a slight clicking noise. If exit shafts other than the chimney flue are provided, they should be short and straight, and capable of being readily cleansed; otherwise friction, and loss of heat by passage of the air through an exposed tube, will stop the current altogether, or reverse it, causing a back-draught. The escaping air must have its temperature kept up, or it cannot escape.

One of the best methods of attaining this object, which might be put into practice in all new buildings, is to construct a shaft at one side of or surrounding the chimney flue, with an inlet near the ceiling of the room, and the outlet at the level of the chimney top. The air escaping from the room will then have its temperature kept up by contact with the chimney flue, thus aiding the up-draught, whilst the risk of reflux of smoke will be avoided. The air flues may be moulded in the same piece of fire-clay as the smoke flue; but those from different rooms should not be connected in any way, or foul air from one room might pass into another.

The combustion of gas may be made a very effective means of getting rid of foul air. It has been found by experiment that the combustion of 1 cubic foot of coal gas causes the discharge of 1,000 cubic feet of air. An extraction shaft may be placed over a gas lamp or chandelier; and by means of a Benham's ventilating globe light, or a Mackinnel's ventilator, slightly warmed fresh air may be admitted at the same time as foul air is extracted.

Mackinnel's ventilator (fig. 30) is very useful for a room which has no other apartment over it. Two tubes, one inside the other, are carried through the ceiling or roof of the building. The inner one, which is for the extraction of foul heated air, projects outside above the outer, and inside also below it. At its lower end a broad circular horizontal rim is attached to the inner tube which deflects the air entering by the outer tube, and causes it to pass for a short distance parallel to the ceiling before falling into the room, as otherwise the fresh air would be drawn round into the inner or exit shaft. The gas burners or lamps used to light the room are placed immediately under the inner tube of this ventilator. The inner or extraction tube should have its top protected by a cover or cowl, to prevent the wind blowing down

and the entrance of rain, which by evaporation might so cool the escaping air as to cause it to be heavier than the air of the apartment. The entering air will be slightly warmed by its passage over the heated extraction shaft. The area of the outer tube for the passage of fresh air should be equal to, or slightly larger (for there is more friction to overcome) than, the area of the inner tube for exit of foul air. Mackinnel's ventilator is well adapted for large buildings, as schools, churches, halls, etc., which have no upper floor or stories. Benham's ventilating globe light, as its name expresses, combines ventilation and lighting; slightly warmed fresh air is admitted, and foul air is extracted along with the products of combustion. In theatres sunlight burners are largely used; they aid the extraction of foul air, but do not admit fresh air.

Extraction shafts, like inlet openings, are liable to have their action reversed under certain circumstances. When the wind is blowing down upon them, when rain gets in, when the escaping air is subject to much cooling in an exposed shaft, or when there are more outlets than one in a room, one predominating over the others, down draughts are likely to occur. This most frequently happens when the draught up the chimney is very great from there being a large fire burning; then there is a tendency for every other opening into a room to become an inlet. Also, when the wind is blowing down an exit shaft or chimney flue, the windows or inlet ventilators may become outlets. These matters can, however, generally be regulated by attention to the facts and principles which have been already laid down as a guide to proper ventilation.

It will be convenient to mention in this place some facts with regard to loss of velocity in air shafts by friction. The actual loss can in some cases be determined by calculating the theoretical velocity in an air shaft by Montgolfier's formula, and then ascertaining practically by means of a current meter or anemometer the actual rate at which the air is issuing or escaping. The difference represents the loss due to friction; but allowance must of course be made for disturbing forces, such as the perflating or aspirating action of the wind. Contrasting two similar tubes of equal sectional area, the loss by friction will be directly as the length of the tube. If the two similar tubes are of unequal size, the loss by friction is inversely as the diameter of the cross-section in each.

When two tubes are dissimilar in shape, the loss by friction is inversely as the square roots of the sectional areas. A circle is a figure which includes the greatest area within the smallest periphery; thus, if there are two tubes, one of which is circular in section and the other square, but having the same area (1 square foot), the loss by friction is directly as the periphery, and in this case is as $\frac{3\frac{1}{2}}{4}$, the periphery of the square being 4 feet and of the circle $3\frac{1}{2}$ feet. Every right angle in a bent shaft diminishes the velocity of the current one-half. It will thus be seen that air shafts should preferably be circular in section, short and straight, so as to diminish the loss by friction as far as possible. The absurdity of ventilating soil pipes and drains by narrow pipes, 1 or 2 inches in diameter, of great length, and bent on themselves often to a right angle, is apparent from the above statements. The ventilation of drains is always difficult to establish; carried out by such methods it becomes an impossibility.

Ventilating appliances whose object is the supply of artificially warmed air are considered in the chapter on Heating and Warming.

Artificial Ventilation.

Under this heading are usually described methods of extraction of air from inhabited buildings by means of heat, steam, or fans, and methods of propulsion of air into buildings by mechanical means. It has been found convenient to describe under natural ventilation of rooms the ventilating effects produced by fires and chimneys in ordinary rooms; and the extractive properties of gas lights have also been alluded to, although, properly speaking, fires and gas are artificial means of ventilation.

Extraction.—The fire and chimney of an ordinary sitting-room are types of the methods used on a larger scale for extraction by heat. The principle is the same in all, and depends on the heating of a column of air in an extraction shaft, which, being thus made lighter, ascends; as long as the heat is applied, a continuous current of air towards the shaft is produced, which in its turn being heated, ascends and escapes, to be replaced by more from below.

It is in this way that some mines are ventilated. The underground workings and galleries of the mine are connected with two large shafts—an upcast shaft and a downcast shaft, usually

from 8 to 12 feet in diameter, leading to the open air; when air is made to pass down the downcast or intake shaft, it has to travel through all the workings of the mine before it can escape by the upcast or return shaft.

The power which produces this continued movement of air may safely be supplied in some mines by a furnace at the bottom of the upcast shaft exerting an extractive force by the heated column of air, as previously described. But in most mines the extractive force is exerted by means of a powerful rotatory exhaust fan placed at the top of the upcast shaft; such fans can be made to propel some 12,000 cubic feet of air per minute. Numerous doors and partitions are necessary in the galleries and workings in order to make the air traverse the whole length of these, and prevent it taking short cuts. An enormous volume of fresh air must be passed through a mine in the course of every hour in order to supply the quantity necessary for the respiration of the men and ponies employed underground, and to withdraw the products of combustion of lights (lamps and candles) and agents used for blasting, and to replace these injurious gases by pure air.

Public halls, hospitals, and other large buildings, are sometimes ventilated on the extraction principle. Shafts for the escape of vitiated air lead from the different rooms and open into the chimney just over the furnace. The air from these shafts should not be used to supply the fire or furnace, but should always open into the flue just above it, where the draught is greatest.

The column of air in an extraction shaft may be heated by steam or hot water pipes, instead of by a fire. This is the plan adopted by the Hopital Lariboisière in Paris. The extraction shaft is heated throughout the greater part of its length by spiral hot water pipes coming from a boiler in the basement. These hot water pipes are also carried into the wards, where they are coiled so as to warm the fresh air entering from without; they then return to the boiler, and thus complete the circuit. The tubes from the wards for the escape of foul air open into the bottom of the extraction shaft. In summer the circulation of hot water in the pipes in the wards is stopped, the circuit being completed by return pipes from the top of the extraction shaft, so that the ventilation continues, but the air entering the wards is not artificially warmed.

The column of air in an extraction shaft may also be heated by gas; but this method is more suitable for the smaller tubes used as exit shafts in ordinary sized dwelling-rooms. Foul air may also be extracted by passing a steam jet into a chimney or upcast shaft. The shafts for the escape of foul air must open into the extraction shaft below the steam jet. The cone of steam emitted from a boiler is said to set in motion and drive before it a body of air equal to 217 times its own bulk.

On board steamships and men-of-war it has been found that very effective ventilation can be obtained by causing the furnaces to extract the air from all parts of the ship through special shafts. By this means also, if the boilers and steam apparatus are enclosed in iron casings, as far as possible, within which the air shafts open, the temperature of the stokehole is greatly reduced.

Some of the chief objections to the method of extraction by heat are: (1) Where the heat is produced by a furnace, it is most difficult to keep this at a constant temperature, consequently the draught is often very irregular. This difficulty is not encountered where the extraction shaft is heated by steam, gas, or hot water pipes, or where the air in it is forced upwards by steam. (2) In all cases where a number of air conduits from rooms at different distances open into an extraction shaft, there is a great tendency to create powerful currents from rooms that are near, and have short conduits leading from them; whilst from the distant apartments with long and perhaps much curved conduits the current may be very slight, or even nil. This difficulty may to a certain extent be overcome by increasing the diameter of the longer pipes so as to reduce the friction, and by bending the shorter pipes so as to increase it; but in practice it is a rather serious drawback. (3) When air is drawn out of a room it is somewhat difficult to control the entrance of fresh air to supply its place, especially with regard to its point of entry and its exclusion from places such as water-closets, from which it is most desirable that no air should be taken.

In the ventilation of factories, steam may often be economically and usefully applied as the extraction force, but extraction by fans has also been largely used, and presents considerable advantages, as the amount of draught can be nicely regulated by altering the speed (the number of revolutions per minute) at which the fan is driven. It is especially in the textile trades—

in the cotton, woollen, silk, worsted, and flax factories—that ventilation is most urgently needed. In many of the processes of these manufactures the work is not only carried on in clouds of dust, but also in greatly heated atmospheres which are saturated with moisture, this being necessary in some instances to the proper performance of the work. To carry off the floating particles of dust it is necessary to induce a powerful current in the exit shaft, so that the air may be drawn in as if to a vortex. In some cases the opening into the exit shaft may be in the centre of the room; but it is more often advisable to carry the dust away as soon as it originates, and before it can mix with the general air of the apartment.

Thus, in the wool sorting trade, each bench on which the wool is sorted has an opening leading by means of a pipe into the extraction shaft, at the extremity of which the exhaust fan is working. When the wool is being shaken, the dust, amongst which may be the spores of *Bacillus anthracis*, is drawn into the tube, and does not mix with the air which is inhaled by the workmen. The dust is then driven into settling chambers, where it is damped by steam jets, and so deposited can be collected and burnt. In silk dressing processes, air tubes are placed above the machinery with dependent hooded openings, which cover the area of dust production and quickly remove the dust; such flues either lead into the chimney flue or have a powerful draught created in them by means of fans placed towards the end of the shaft which leads from them to the outside air. In the dry grinding processes of the metal trades, the air tubes are placed level with the grindstones and have openings opposite each stone in such positions as to catch the dust as it is driven off, and carry it away at once. The best material for the exit shafts and tubes is galvanized sheet iron, as it can be made into smooth circular pipes. Arrangements must be made to provide that the draught from the benches, or the workrooms nearest the fan, is not so great as to prevent the shafts at a distance from working properly. For clearing away the steam from the washing rooms of laundries, etc., fans may be effectually employed, either for extraction or for driving in warmed air.

Propulsion.—Convenient forms of fan are those known as the Blackman Air Propeller and the Sutcliffe electric fan; they can be used for exhaustion (vacuum ventilation) or for propulsion (plenum ventilation). Another good form of fan, which is

noiseless in its working, is that known as the Sturtevant "blower." They can be driven by a gas or steam engine, by water or electricity, and are employed for removing dust, foul air, or fumes and steam. When used for propelling air into a building, the rate of movement in the main conduit should not exceed 5 feet per second, and, where delivered into the rooms, not more than $1\frac{1}{2}$ or 2 feet per second. The sectional area of the air shafts should be at least equal to that of the fan, so as to reduce resistance by friction. Any filtering or washing screens provided should have a superficial area amounting to at least six times the

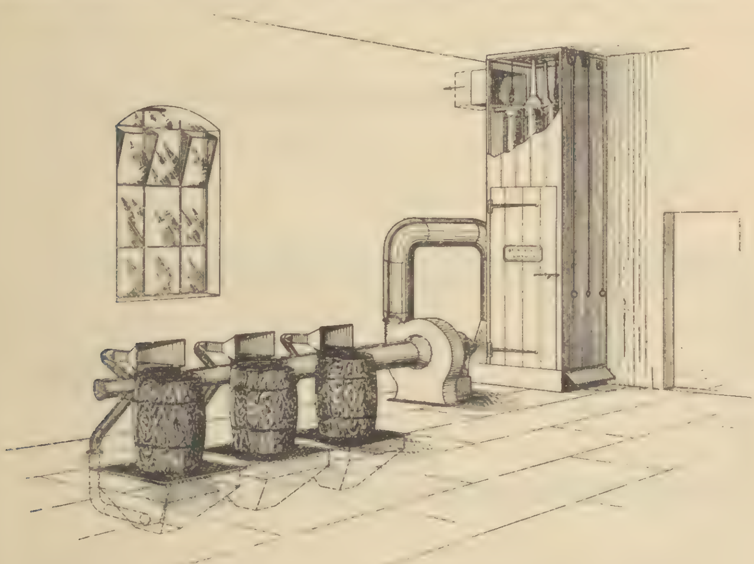


FIG. 31.—STURTEVANT PNEUMATIC DUST COLLECTING SYSTEM.

area of the fan. The warmed fresh air should be delivered by the pipes into the rooms. Special exit shafts are not always necessary, and those existing near the ceiling should be closed. The air finds its way out through fireplaces, doors, windows, or the innumerable minute apertures by which every room communicates with the exterior. In the "plenum" system, windows, etc., are kept closed, so that the air being constantly driven into the rooms is under a slight pressure, which causes it to escape through the exit opening or openings communicating with special exit shafts. These exit openings should be low down in the rooms or workshops, and principally on the same side of the

room as the inlets, so as to cause the incoming air to circulate thoroughly before it escapes. Mechanical ventilation by means of fans is now much used in public halls and restaurants, and is advocated for school classrooms.

The objections to the propulsion or "plenum" system of ventilating buildings is that experience shows that the air has lost its freshness and is liable to cause lassitude and a feeling of depression amongst those who habitually come under its influence.

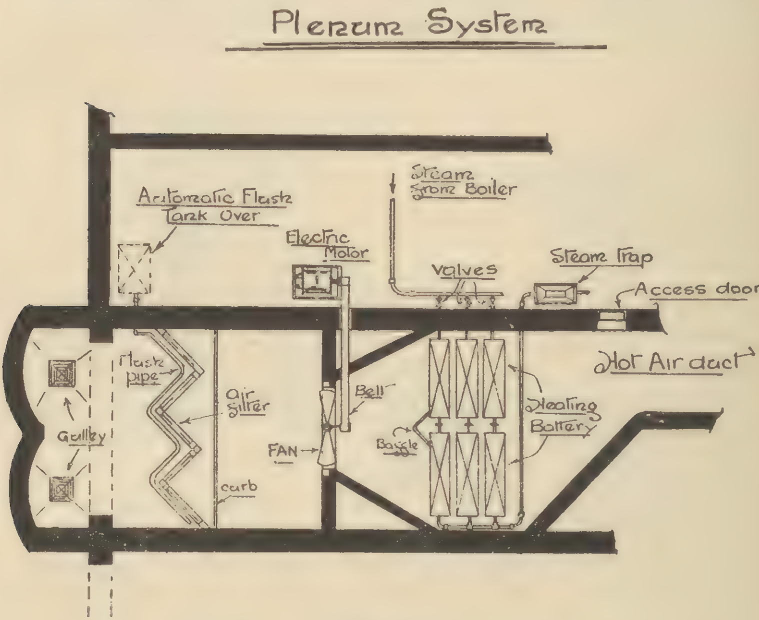


FIG. 32.

Chemical and bacterioscopic examination may demonstrate the purity of such air, but none the less there is reason to believe that in such air the tonic principle characteristic of really fresh air is diminished. The very artificiality of the plenum system, which permits of the air supply being regulated with great nicety as to rate of movement, temperature, moisture, etc., robs it at the same time of the refreshing qualities so important for the maintenance of a good standard of health. Open windows and direct ventilation through the external walls of a building may cause draughts and irregularities of temperature, but such methods appear to be more healthful for hospitals and buildings

of the factory and domestic class, which are more or less continuously occupied, than the artificial systems of ventilation. For theatres, churches, concert halls, etc., where large numbers are collected for limited periods only, artificial systems of ventilation find their best application; but in the plenum system the permanently closed windows constitute a very bad object-lesson to scholars at school.

But ventilation by propulsion (plenum method) presents several advantages. The amount of air delivered and the rate of movement can be regulated with nicety, and the entering air can be taken from the most desirable point, can be warmed or cooled in special chambers by a spray of water, and filtered through suitably graded coke or cocoa-nut fibre screens, kept moist by water, or through a very fine meshwork of copper wire continuously sprayed by water; and all this can be done at one spot for a number of rooms or buildings. A more frequent air renewal can be provided by this than by any other method, and less dirt is introduced from without.

In the Houses of Parliament at Westminster a combined method of ventilation by propulsion and extraction by fans is in operation. Air is propelled by rotary fans along conduits to the basement, where it is filtered through cotton-wool and warmed in winter by passing over steam pipes, and then passes upward through shafts into the space beneath the grated floor of the House. The heat can be regulated by covering the steam pipes with woollen cloths, and in summer the entering air can be sprayed with water or cooled by passing over ice. The vitiated air in the House passes through a perforated glass ceiling in the roof, and is then conducted by a shaft to the basement of the clock tower, where it passes into a flue from which the air is extracted by a rotary fan.

The ventilation of the Debating Chamber in the House of Commons does not, however, appear to be very satisfactory, and is frequently complained of. The entry of air through mats on the floor, which have been dirtied by the boots of members, is evidently not an ideal method of securing purity of air.

What is known as the "balance" system—a combination of plenum and vacuum—is specially applicable for the ventilation of large halls and rooms with extensive seating capacity. In the large Examination Hall of the University of Cambridge this system has been successfully applied. Warm fresh air is intro-

duced on opposite sides of the hall, about 7 feet above the floor, by means of a fan, and is extracted by another fan from apertures in the ceiling leading to an extraction shaft. The building is warmed prior to use by hot water radiators ranged along the four walls—it being far more economical to warm a building in this way than to attempt to warm it by the heat conveyed in the warmed fresh air used for ventilation. The windows of the hall are double glazed, the air space between the two sheets of glass forming a non-conducting layer, which not only prevents loss of heat by radiation from the interior of the building, but also tends to minimize the interference with the proper direction of the ventilating currents, which is caused by chilling of the air in the neighbourhood of the windows. In this "balance" system, when the inlet and outlet fans are properly adjusted, there is neither excess nor reduced pressure maintained within the building. There is, therefore, no tendency, on the one hand, for air to escape, nor, on the other, for air to enter, except at the proper inlets and outlets, and the distribution of the air is kept under very perfect control.

In Verity's system, air is set in motion by a spray of water from a number of very fine jets. The rate of motion can be regulated by the tap which supplies the jet. The method is useful for houses where it is not desired to go to the expense of fans driven by machinery.

In addition to hot water pipes, incoming air may be warmed by passing it into firebrick chambers, or through air ducts, placed behind and at the sides of a fire grate or stove; or the air may be warmed by conducting it through a tube which passes through the centre of a gas stove (George's Calorigen and Bond's Euthermic, fig. 34).

The Manchester stove is largely used for schools, hospitals, etc. In this stove the cold air is carried along a shaft placed between the joists of the flooring, and enters a firebrick chamber built into the back of the grate. It then passes through tubes leading from the top of this chamber, and, travelling round the hottest part of the smoke flue, enters the room through openings at the top of the stove. The smoke flue is bent back and carried down the back of the stove, passing under the flooring to the outside, where it is carried up as a chimney.

In all systems of ventilation it is important to remember that air ducts of all kinds should be made easily accessible for clean-

ing. This principle has been too often neglected in the past, with the result that air fouled by contact with dirt is very frequently used to supply buildings, whilst outlet pipes and shafts are found choked with accumulations and practically valueless.

As a means of reducing high temperatures the "douche system," in which a stream of cold air is driven by fans into the general circulation of air when the men are at work in factories, has been found to lead to better working conditions, favouring greater production and less fatigue. To reduce the expense entailed, mainly by saving fuel, the recirculation of the used air drawn from the workshop has been suggested and introduced in various parts of the United States, and where there is ample air space and the vitiation is of purely human origin, it has proved satisfactory. This method has been also recommended for school classrooms, for which it is claimed that, so long as the temperature is maintained below 70° F., all hygienic requirements will be fulfilled and humidification would usually be unnecessary.

Ozonization of Air.—This has been recommended for the deodorization of foul atmospheres and for the destruction of the organic matters and living microbes that may be present in such air. The amount of ozone in the air, which is produced by the use of the apparatus of the Ozonair Company, is ordinarily from 1 to 5 parts per million, the limit for comfortable respiration being about 10 parts per million; above this amount the irritating effect on the mucous membranes of nose, eye, and throat begins to get very marked. In the Ozonair Company's apparatus, ozone is produced by the action of an alternating electric current of high frequency on the oxygen of the air, through the medium of a non-sparking or silent (condenser) discharge, no oxide compounds of nitrogen being formed by this form of discharge. The machine, when at work, emits a continuous stream of ozonized air, which for ventilating purposes is mixed with ordinary atmospheric air, the resulting mixture having the composition above mentioned (1 to 5 parts per million of ozone). The characteristic smell of electrically produced ozone is noticeable in air containing these small amounts of the gas, but it is not disagreeable, nor are there any irritating effects on the mucous membranes of the eye, nose, or throat, probably because of the absence of oxides of nitrogen.

Air ozonized to the extent that is compatible with comfort is a safe and valuable deodorant. Whether volatile organic matters in the air are actually oxidized and destroyed by these very weak dilutions of ozone, or are merely masked and rendered inappreciable by the penetrating odour of the gas, is a matter of uncertainty. What, however, is certain is that, in the very weak dilutions that can be inhaled with safety, ozone has no sterilizing or disinfectant action on air-borne micro-organisms. To destroy the *Bacillus typhosus* in dry air there must be present 0·3 per cent. of ozone in the air (3,000 volumes per million), and the bacilli must be allowed to remain in contact with the ozonized air for one hour, otherwise disinfection is incomplete. The bacilli of tubercle, influenza, diphtheria, and nasal catarrh are probably not less, but more, resistant than the *B. typhosus*, so that it is evident that an atmosphere containing 10 parts per 1,000,000 of ozone—the limit for respirability—has only $\frac{1}{300}$th part of the amount of ozone requisite to destroy pathogenic organisms, which must be left in contact with it for an hour at least.

Practical Examination of the Ventilation of Inhabited Rooms.

In the first place it is necessary to determine the amount of cubic space. In rooms of regular shape this may be done by multiplying together the three dimensions of height, length, and breadth. If the room is irregular in form, containing recesses and projections, or with a raised ceiling, it is usually most convenient to divide it up into a number of simpler parts, whose cubic contents can be determined by some one or more of the following rules:

Area of circle = square of diameter (D^2) × 0·7854.
Circumference of circle = D × 3·1416.
Area of ellipse = the product of the two diameters × 0·7854.
Circumference of ellipse = half the sum of the two diameters × 3·1416.
Area of square = square of one of the sides.
Area of rectangle = the product of two adjacent sides.
Area of triangle = base × ½ height.
Area of a parallelogram = divide into two triangles by a diagonal, and take the sum of the areas of the two triangles.

Area of trapezoid = half the sum of the parallel sides $\times$ the perpendicular distance between them. A trapezoid is a plane four-sided figure having two of its opposite sides parallel.

Area of segment of circle $= (\mathrm{Ch} \times \mathrm{H} \times \frac{2}{3}) \times \frac{\mathrm{H}^3}{2\,\mathrm{Ch}}$

(Ch = chord, H = height).

Cubic capacity of cube or solid rectangle = length $\times$ height $\times$ breadth.

Cubic capacity of solid triangle = area of triangle $\times \frac{1}{3}$ height.

Cubic capacity of cylinder = area of base (circle) $\times$ height.

Cubic capacity of cone or pyramid = area of base (circle) $\times \frac{1}{3}$ height.

Cubic capacity of dome = area of base (circle) $\times \frac{2}{3}$ height.

Cubic capacity of sphere $= \mathrm{D}^3 \times 0{\cdot}5236$.

Thus, supposing it was required to determine the cubic capacity of a circular hospital ward 30 feet in diameter, with walls 10 feet high, and a dome-shaped roof 5 feet high. The area of the base or floor space is 706·86 square feet. The cubic capacity of the cylinder below the dome is $706{\cdot}86 \times 10 = 7{,}068{\cdot}6$ cubic feet, to which must be added the cubic capacity of the dome = 2,356·2 cubic feet. So that the cubic capacity of the ward is 9,424·8 cubic feet.

Having determined the gross cubic space, the next point is to determine the available cubic space, *i.e.*, the gross cubic space less the space occupied by solid objects in the room. Any bulky furniture must of course be measured, and it is usual to deduct 3 cubic feet as the space occupied by each individual, and 10 cubic feet for each bed and occupant. Having made these deductions, the available space for ventilation is arrived at. Next, the various openings acting as inlets and outlets respectively must be determined, and thus the area of inlet and outlet provision per head can be ascertained. To distinguish inlets from outlets, observe the direction given to the smoke evolved from smouldering brown paper or cotton velvet, when held close to the apertures, some of which will be found to act as inlets and others as outlets. The rate of movement of air through these apertures may be approximately ascertained by placing in them an anemometer, which is an instrument consisting of four little revolving sails driven by the wind or current of air. The sails

turn an axis with an endless screw running on small toothed wheels, which, by means of a plate and dial, indicate the number of revolutions of the axis and the space traversed by the sails. By experiment with air moving at a known rate of speed, the anemometer may be graduated. It appears, however, that even tested anemometers are subject to variations, and too much reliance must not be placed on their indications. When the instrument is placed in a ventilating shaft or opening, it should be at about two-fifths of the distance from the centre to the margin of the opening, that being the situation where the mean velocity is obtained with the greatest degree of approximation. A modification of the water manometer, or pressure gauge, is occasionally used. The current of air impinges on the surface of the water in one arm of a bent tube, and in proportion to its strength drives the water up the other arm, which is inclined at a certain angle. The records obtained in this manner can be compared with the theoretical velocities arrived at by the use of Montgolfier's formula, allowances being of course made for friction and wind. When the wind is at all strong and is blowing directly into inlet ventilators, or is exerting a powerful aspirating action on chimneys or exit shafts, calculation is useless.

As air enters a room by every crack and crevice, and may even do so through the brickwork of the wall, it is practically impossible to gauge the amount of the incoming air. The best plan is to deduce it from the amount which is leaving the room, as the outgoing air will only leave the room by well-defined channels or outlets. In an ordinary room practically the whole of such air tends to escape by the fireplace, the entrance to the flue of which has generally a transverse section of about 126 square inches. If the rate at which the air is travelling up the chimney is ascertained by an anemometer, the amount of air leaving the room is easily calculated. Thus, assuming the velocity to be 7 feet per second, then the quantity of air escaping will equal this velocity $\times$ the sectional area of the opening (in feet) $= 7 \times \frac{126}{144} = 6{\cdot}1$ cubic feet per second, or 21,960 cubic feet per hour. If samples of the air are to be taken for an estimation of the CO_2, any gas burners, lamps, etc., which may be alight at the time must be carefully noted, together with the temperature at the time the sample is taken.

In any scheme of ventilation, regard must be had to the following practical points:—

1. When air is heated it expands and tends to rise; when air is cooled it contracts and tends to fall.

2. Cold air tends to enter a room and to move about very much as water would; and this holds true so long as the temperature of the fresh air remains lower than that in the room.

3. The extent of inlet provision for fresh air is not quite of the same importance as that for the exit of foul air; for if foul air is extracted in sufficient quantities, fresh air will enter somehow to replace it, as by skirtings, crevices in doors and windows, or even through the brickwork of the walls.

4. The inlet provision for fresh air should average 24 square inches for each individual; the provision of inlet areas somewhat larger than those of exit tends to minimize draughts.

5. Inlets should generally be as low in the room as possible, viz., just above the floor (so as not to raise the dust) if the outside air is warm or has been warmed prior to entry, but at a height of about 5 feet if the outside air is cold; otherwise unpleasant draughts are experienced. As a further protection against unpleasant draughts when cold air is admitted, the incoming air should be directed upwards.

6. Outlets should in every case be as high as possible, and preferably close to or in the ceiling; and for the best results they should have their extractive powers maintained by means of heat or an exhaust fan, or they are liable to act as inlets.

7. Where practicable, an effort should be made to so place outlets that the vitiated air is drawn towards them before mixing with the general air of the apartment.

8. There is a tendency for fresh air to take a direct course to the outlets, and this must be counterbalanced by a judicious selection of the relative positions of inlets and outlets.

9. Methods of ventilation devised to ventilate *crowded* premises are generally inefficient, unless the incoming air can be warmed in winter to about 60° F.; for then efficient ventilation by cold air cannot be tolerated, and there is a great tendency among workers to close all ventilating inlets.

10. With less than 250 cubic feet of space per head, no ventilation can be satisfactory which is not aided by mechanical force.

11. The source of the incoming air should be considered. It should not be borrowed from adjoining rooms, but taken direct

from the outside. One great advantage of the more expensive mechanical system of plenum ventilation is the fact that sufficient air can always be obtained from a source which is known and selected.

12. Ventilation dependent on the extraction of foul air is often more convenient than that in which propulsion is mainly relied upon; but the purity of the air is not so easily provided for or guaranteed.

13. If warmed air is forced into a room, it should only be raised to a temperature sufficient to prevent a feeling of cold (about 60° F.). More highly heated air is often felt to be overdry and unpleasant.

14. The heating of the room should be effected by fires, stoves, or pipes in the room itself, and should never be made to depend upon the warmth of the incoming air.

15. It is difficult and expensive to apply methods of mechanical ventilation to old premises.

CHAPTER IV

WARMING AND LIGHTING

WARMING.

INDIVIDUAL susceptibilities to heat and cold are various, depending as they do upon age, robustness of constitution, and previous habitude. It may, however, be stated that, as a general rule, the temperature of a sitting-room or workroom should be from 60° F. to 65° F.

Radiation.

In this country houses are generally warmed by radiant heat from open fire-places. By radiation is meant the direct passage of heat from warm bodies to colder ones, the rays of heat passing through the intervening air. This form of heat is no doubt the most healthy, for whilst objects within the range of the fire are warmed, no impurities are added to the air of the room. Moreover, the column of air in the chimney flue is heated, and, becoming lighter, escapes at the roof of the house, to be replaced by colder and denser air from below, and thus an open fire-place is a great factor in ventilation. It is, however, extremely wasteful, for the greater part of the heat escapes up the chimney.

The intensity of radiant heat is inversely as the square of the distance of the heated object from the source of heat. Thus, if there are two objects, 1 foot and 3 feet distant (respectively) from an open fire-place, the more distant object only receives one-ninth the amount of heat received by the nearer object. This fact shows the impossibility of warming equally all parts of a room, when the source of heat is an open fire-place.

Of late much has been done to improve open fire-places by securing the greatest amount of heating effect with the least consumption of fuel. Some of these improvements were made at the suggestion of the late Mr. Pridgin Teale. They may be thus summarized: The width of the grate at the back should be about one-third the width in front facing the room, the sides of

the grate being splayed out at the necessary angle. The back and sides of the grate should be formed of fireclay, and the back, instead of rising perpendicularly, should be "rifle-backed," *i.e.*, curved forward so that the flames may play upon it (fig. 33). The curved portion becomes heated by some of the upward rays, which would otherwise be lost up the chimney, and radiates this heat into the room. Vertical fire bars are said to allow more heat to radiate into the room than horizontal bars.

The floor of the grate should be formed of a solid slab of fireclay, as in slow combustion grates; or if the lower fire bars are retained, a shield should be placed on the hearth, rising as high as the bottom bar of the grate, so as to form a hot air chamber under the grate completely cutting off the air of the room (fig. 33); or an iron plate may be laid upon the bars forming the bottom of the grate. The object of this arrangement is to prevent a draught under a fire which hastens combustion and wastes fuel.

FIG. 33.—RIFLE-BACK STOVE WITH ECONOMIZER.
A, hot air chamber; *B*, flue.

The whole fire-place should be brought well forward into the room, the grate being placed low down near the floor, and to reduce draught the chimney throat should be narrowed as much as possible. A movable hinged canopy, to regulate the draught up the chimney, is a desirable arrangement.

Open grates of this description create much smoke, as the combustion of the fuel is by no means complete. Attempts have been made to construct a smokeless open grate; and the plan which has been found on the whole to answer the best is to "underfeed" the fire, by which is meant that the supply of fresh fuel is introduced beneath the incandescent coal which forms the top of the fire, and through which the smoke arising from the fresh coal must pass, thus securing complete combustion.

In one of the best of these smokeless fire-places a curved ledge projects from the bottom of the grate. The fresh fuel is placed on this ledge and forced under the blazing coal above by means of a special kind of shovel. These "underfed" grates are found to be very efficient heaters for the amount of coal consumed, and they continuously expose a clear fire free from smoke, but they require more care in stoking and management than ordinary grates.

Taking 25 per cent. as representing the performance of a good type of modern coal fire-place, and allowing an additional 5 per cent. for heat which is convected into the room, it would seem that, so far as heating the room is concerned, the fire utilizes about 30 per cent. of the total heat developed by the combustion of the fuel. The remainder passes up the chimney, but is not wholly lost, because some of it is taken up by the walls, and is therefore usefully employed in warming the other rooms of the house. There is one feature about the radiation from a coal fire—namely, its variability of intensity—which ought to be borne in mind; because if monotony of conditions in our heating arrangements is to be avoided, perhaps the coal fire as nearly fulfils such an ideal as anything yet devised (Bone).

Wherever possible, fire-places and chimney flues should be built in one of the inner walls of a house. The waste heat of the flue will then help to warm the upper rooms. It is evident that, as open fire-places act as ventilators for extraction of air, to carry on this function the column of air in the flue must be kept continuously heated; otherwise the chimney will not "draw," and back currents of smoke enter the room. In an ideal stove, the heat escaping up the chimney should be not more than sufficient to maintain a good draught, the rest being radiated into the room.

There are several forms of "slow combustion" grates now upon the market, the principle of which is to reduce the draught through the fire to its smallest possible dimensions. One of these, the "Well Fire," consists of a fireclay trough, inside which is placed a cast-iron grate whereon the fire rests. The space between the iron and the fireclay constitutes a hot air chamber to which a continuous current of air at a raised temperature is admitted by side tubes.

With a reduction in the price of coal gas, open gas fires have come more largely into use. As usually constructed, the flames

from a row of Bunsen burners play upon asbestos, in lumps or fibre, or upon vertical open-work fireclay burners, which become heated to a red heat. A gas fire consumes from 10 to 20 or more cubic feet of gas per hour. Until gas is supplied at 1*s*. or 1*s*. 6*d*. per 1,000 cubic feet, which could easily be done if it were freed from illuminants, or until a public supply of *water gas* is made safe and available, gas fires must be more expensive than coal. But they have the advantage of being very cleanly—there is no soot in the chimney flue and no dust or ashes—very convenient, and of causing no trouble. As regards the prevention of smoke, the more extended use in our large towns of coal gas for heating and cooking would undoubtedly tend to free the air from much of the soot and smoke that now pollute it. Fogs, which depend so largely upon climate and site, would be just as frequent, though less sooty and yellow. They would also be less sulphurous, for the sulphur compounds produced by gas combustion are less than those produced by coal.

It is probable that *water gas* would come largely into use for heating and illuminating purposes—for gas fires and gas cooking stoves, and for incandescent burners—were it not dangerous, from containing such a large percentage of carbonic oxide.

Water gas is produced by blowing steam through incandescent coke or other carbonaceous matter, raised to a high temperature in a "generator" furnace by the aid of an air blast. The incandescent coke gives off what is known as "producer gas," and this is led away from the generator before the steam is introduced. The introduction of the steam is only continued for about four minutes, after which time it is necessary to turn on the air blast again to reheat the coke. The "producer gas," consisting largely of carbonic oxide, is used for heating the boilers which generate the steam. It will thus be seen that the process consists of alternately blowing the generator hot (for ten minutes), when producer gas is formed and led away, and of making water gas by introducing steam over the hot fuel (for four minutes). In this way the water is split up into hydrogen and oxygen; the hydrogen remains free, and the oxygen with most of the carbon forms carbon monoxide, the mixture being "water gas." The water gas, as formed, is passed over scrubbers and purified over oxide of iron, in much the same way as coal gas, before being stored in gas holders; it then consists of hydrogen gas (about 35 per cent.) and of carbonic oxide (25 to 35 per cent.), marsh gas 20 per cent., and 10 per cent. of other gases. In heating power water gas is far superior to coal gas; and as the only products of combustion are H_2O vapour and CO_2, the sulphur products of combustion of coal gas are avoided. Water gas, too, can be produced very cheaply, viz., at about 4*d*. per 1,000 cubic feet. But the large

quantity of CO in water gas causes it to act as a powerful poison, and yet, from being odourless, escapes, if they occur, are not at once detected. For lighting purposes the gas is "carburetted"—that is, enriched by hydrocarbons derived from oil. This carburetted water gas smells much like coal gas; its candle power is greater, and it is, on the whole, cheaper to make. It has been adopted for lighting purposes in many towns in America, and it is often used, mixed with coal gas, in this country. A Departmental Committee recommended a statutory limit of 12 per cent. of CO in any illuminating gas; for an escape leading to the presence of 0·3 per cent. of CO in the general atmosphere may prove fatal.

A more recent Departmental Committee has not recommended any limitations to the proportion of CO which may be supplied in gas used for domestic purposes, the distinctive odour of coal gas being held to furnish a sufficient indication of danger; and against any very occasional loss of life must be set the improvement in the public health which will result from the reduction of smoke and fog owing to the increased use of gas. This decision has by no means met with a general acceptance.

It is perhaps needless to point out that plumbers should never be allowed to fix a gas fire, or, in fact, any gas-consuming appliance (such as a bath heater or "geyser"), which burns more than 12 feet of gas per hour, without providing a chimney flue to carry off the products of combustion to the outer air.

Ventilating grates may be combined with open fire-places. The usual method is to construct a chamber lined with fireclay at the back and sides of the fire-place, and extending up around the lower part of the chimney flue. An opening below admits fresh air from outside the house into the chamber, where it is warmed and escapes by an opening into the room above the chimney-piece. Galton's Grate and the Manchester School Grate act upon this principle.

Electric radiators, as sources of heat, have been much improved in recent years; but with the relative prices of coal, gas, and electricity, which are likely to be maintained, the same amount of heat can be developed much more cheaply by the consumption of coal (or coke) than by that of either coal gas or electricity.

Conduction and Convection.

By conduction heat passes from one molecule of air to another in contact with it; but, as air is a very bad conductor of heat, the process is very slow. The conveyance of heat by means of

the movements of masses of heated air (convection) is the most effectual agent for heating. Air when heated expands and becomes lighter bulk for bulk than colder air, so it rises upwards, its place being taken by the colder, denser air.

Houses may be heated by means of stoves in which coal, coke, gas, or oil is burnt, by hot water and steam pipes, or by "radiators," which furnish but little radiant heat, and warm a room mainly by convection. The air coming in contact with the heated surfaces is warmed, and therefore expands and rises, and is replaced by colder air. In this way currents of air are maintained which, circulating about a room, tend to heat every part of it. The most satisfactory way of uniformly heating the whole house is by warming the air of the entrance hall by means of hot water pipes, a hot water radiator connected with the kitchen boiler, or a ventilating stove placed in the hall. The warm air which ascends can then be admitted to all the rooms above the ground floor by openings over the doors, which openings may be fitted with valves.

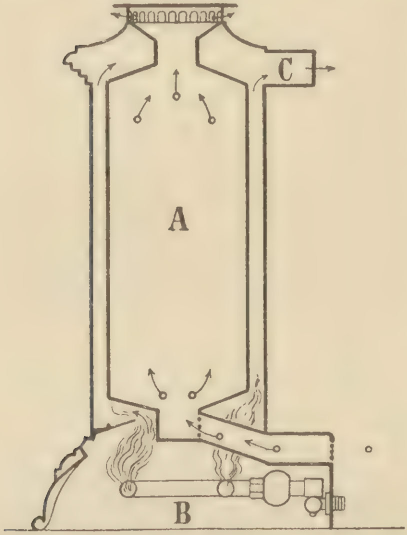


FIG. 34.—EUTHERMIC VENTILATING GAS STOVE.

A, fresh air chamber; B, ring of Bunsen gas burners; C, to foul air flue.

The great distinction between stoves and open fire-places is that, whilst in the latter the heated air escapes up the chimney, in the former the heated air circulates through the room.

There is a great variety of heating stoves, but they may all be classified as either *close* or *ventilating* stoves. In the former kind no arrangement exists for providing fresh warmed air; whilst in the latter fresh air from outside the house is made to circulate through the stove, without coming into contact with the products of combustion, and is, when warmed, allowed to enter the room. Bond's Euthermic Stove is one of the best forms of ventilating

stove. In this the fresh air from the outside is conveyed to and warmed in a central upright tube, which communicates with the room at the top of the stove. The space between this tube and the outer case of the stove is open below, where a circle of gas jets burn, and above it communicates with a flue. Thus, not only is warmed fresh air supplied to the room, but also foul air is removed along with the products of combustion between the inner tube and the outer case.

From an inquiry undertaken by the *Lancet* into the general efficiency of gas stoves, the following facts emerged: A properly constructed gas stove with a suitable flue, while more costly than a coal fire, does not vitiate the air of a room nor produce any abnormal drying effect upon it; more heat is lost in the flue gases in coal fires than in gas fires; coal fires take longer to warm a room than gas fires; as gas fires are so easily regulated, the temperature of a room can be controlled in a manner which is not possible with coal fires, and a more equable temperature is maintained with a gas fire with an absence of dust and smoke; no carbon monoxide was detected in the hot air and gases coming from these stoves, except in one instance where the stove was faulty.

In all stoves economy of fuel is aimed at, by providing doors and dampers to shut off the draught and make the combustion as slow as possible; and the flues are sometimes carried horizontally for some distance, in order that extra heat may be obtained. It is evident that the slower the combustion and the more complete the utilization of the heat of the burning fuel in warming the room, the less does a close stove act as an exhaust ventilator, and economy of fuel and utilization of heat may be procured at the expense of healthiness.

The ventilating stoves which introduce a supply of fresh warmed air are decidedly more healthy; but there are certain disadvantages which require consideration in the use of stoves of all kinds.

In the first place, they are apt to render the air of a room too dry, and therefore unpleasant to the nose, eyes, and skin. There may be the same amount of moisture in a cubic foot of heated air as in a similar bulk of cold air before it is warmed; but the relative humidity of the air when heated would be greatly diminished, as hot air is capable of holding more moisture, before saturation is reached, than cold air; and it is upon relative

humidity to some extent that health and comfort depend. This drawback may, to a certain extent, be overcome by placing vessels of water in the room or on the stove.

Secondly, if the stove becomes overheated, the organic matters in the air become charred by contact with the heated surface, and a disagreeable close smell is perceived.

Lastly, the presence of carbonic oxide has been detected in the air of stove-heated rooms when the stove is of cast iron. Either this gas passes out of the furnace through invisible fissures in the cast iron, or it traverses the walls of the stove when at a red heat. Others suppose that the gas may be formed by incomplete combustion of particles of carbon or organic matter floating in the air, when brought into contact with the hot metal.

Cast-iron stoves are very liable to become overheated, as, being good conductors, they rapidly heat and cool. In such stoves, therefore, the heating surface should be increased by vertical flanges projecting from the top and sides, by which means the heat, being conveyed to a larger surface, is less intense, because cooling is more rapid. It is safer not to use cast-iron stoves at all, unless lined inside with fireclay; this, being a good non-conductor, prevents the over rapid heating of the iron walls, and the warming of the room is altogether more equable. There are many ornamental stoves now made entirely of fireclay and china, with arrangements for the supply of warmed fresh air at an agreeable temperature of about 65° to 70° F. They are especially valuable for heating halls and public buildings.

No ill effects appear to follow upon the use of oil stoves in living rooms, if the combustion of the oil is complete and there is efficient air renewal in the room, despite the general absence of flues to convey away the products of combustion.

Steam pipes are largely used for heating factories and workshops and public buildings where steam power and waste steam are at hand.

Systems of Heating by Hot Water or Steam.

The impossibility of adequately warming large rooms, halls, theatres, and other public buildings by open fire-places or stoves has led to the adoption of various systems of hot water or steam heating, of which the principal varieties in use are:

High Pressure Gravity Hot Water.—The pipes are of welded

wrought iron of small diameter ($\frac{7}{8}$ inch internal diameter). There is no boiler, the water being heated by a coil of the piping, of about one-sixth the total length, passing through a brick furnace. An expansion tank is connected to the highest point of the system, in which is fixed a combined "blow off" and "suction" valve. As the water expands on heating, the valve

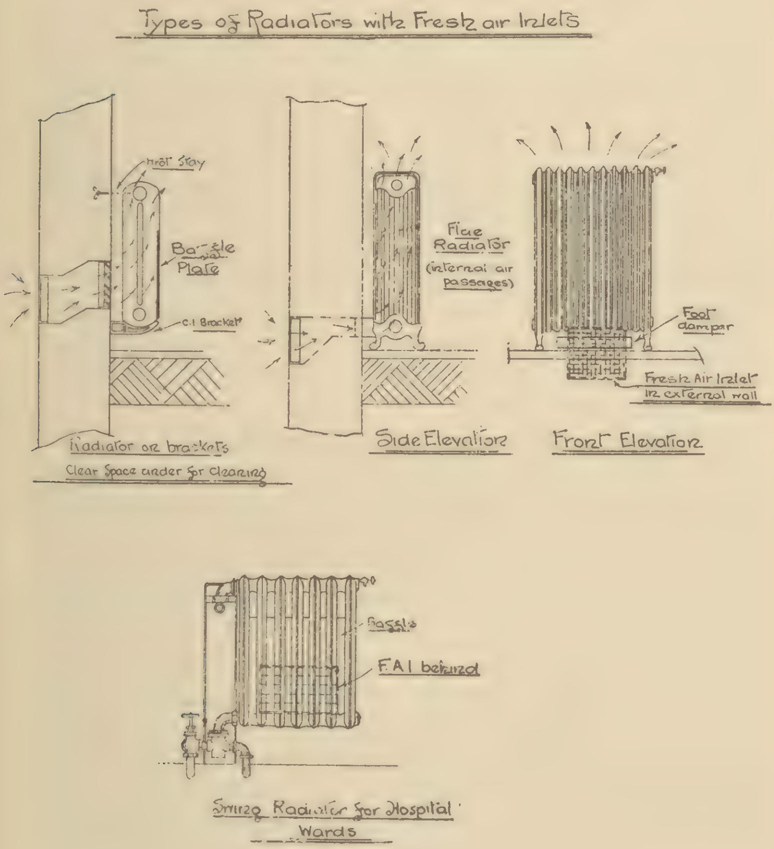


FIG. 35.

lifts off its seat, and the surplus water escapes into the expansion tank, until the proper working pressure is reached. When the furnace is drawn or not replenished, the water in the pipes cools, contracts, and creates a vacuum. The suction valve then comes into action, and water passes from the tank into the pipes. The water, being under pressure, can be heated to 300° or 350° F.;

but although this renders the system efficient as a heat producer, the high temperature of the heating surface causes an unpleasant, stuffy atmosphere—probably from charring of organic matter in the air. Such atmospheres are often productive of headache, lassitude, and dry sensations in the throat, the latter being due to overdrying of the air (low relative humidity).

Low Pressure Gravity Hot Water—(1) *Heating by Hot Water Pipes.*—In this system 2 or 3 inch cast-iron pipes are connected with a boiler at the base of the system, so as to provide a complete circulation. The water is heated in the boiler, circulates through the pipes, parting with some of its heat to the air in contact with them, and on cooling returns to the boiler, the circulation being due to the difference between the specific gravities of the water in the flow and return pipes. An expansion tank is connected to the highest point of the system to allow for increase in volume of the water when heated, and the tank is supplied with water from the house supply by a ball valve. At the highest point of the system, or at any place where air is likely to collect, a small air escape pipe should be carried to the outer air.

(2) *Heating by Radiators.*—In this system the circulating pipes are of small diameter (about an inch or less), and the heating effect is produced by radiators fixed at convenient points, the radiators being vertical pipe coils of ornamental pattern. Each radiator is controlled by a valve to entirely or partially cut off the flow of water through it, and thus the temperature can be regulated to some degree of nicety. An air-cock is also provided to allow air to escape when the radiator is filling.

The great advantage of these two systems is that the heating surfaces are maintained at a comparatively low temperature, seldom rising above 180° F., and there is, in consequence, very much less tendency for the air to become stuffy from overheating and overdrying. The system is simple, is inexpensive to install and maintain, and the boiler only requires stoking at long intervals. On the other hand, in buildings of irregular shape and height there may be some difficulty in maintaining a regular and even flow of water through all parts of the system, and air-locks often give rise to trouble.

Low Pressure Hot Water, with Assisted Circulation.—To overcome the difficulties arising from irregular flow, when the force of gravity alone is depended upon, the use of steam to assist the

flow has been successfully applied. In Barker's "cable" system, steam is led from a boiler into an apparatus consisting of two chambers side by side. In the first chamber, the water to be heated comes in contact with the live steam by falling in drops through a perforated tray. On reaching a certain height in the chamber, the heated water opens a valve, and passes into the second chamber. When this chamber is full, a valve is opened which admits steam, and the heated water is forced by steam pressure into an expansion tank above the apparatus, from whence it passes into the main flow pipe leading to the radiators, and thence by a return main to the first chamber. In this chamber the condensation of the steam, as it heats the incoming water, causes a partial vacuum, which very materially aids the return flow of water. The whole work of the apparatus is automatic, and requires no attention. It will be seen that the hot water is forced to travel through the system by steam pressure and gravity, and is aided in its return by the suction induced by steam condensation. It is due to this that very small pipes only are required for the mains and branches, and considerable obstacles in the way of dips can be overcome, as the motive forces render the system very largely independent of friction. The temperature of the circulating water can be regulated to anything between 100° F. and 200° F., the temperature usually employed being 150° F. or 160° F., so as not to overheat or overdry the air.

The invention of the "assisted" hot water circulation has enabled a novel method of heating to be introduced, which would not have been possible without it. In this system the pipes, which need be only of small diameter—less than 1 inch—are laid in a composition material similar to those now in use for floors, and consisting for the most part of compressed sawdust, cement, and asbestos. This material, with its contained hot water pipes, is laid as panels in the floor or walls of a room, and the room is heated by its warm floor or walls. The surface temperature of the panel is a low one, so that there is no risk of overdrying or of overheating the air; and the source of heat being low down, near or at the floor level, the feet of the occupants are kept warm, and cold currents of air near the floor level, causing "cold feet," are avoided. A very comfortable equable temperature is obtained by the "panel" system of heating, and there are no unsightly pipes, radiators, or other fittings to

detract from the architectural or decorative amenities of the apartment.

There are various systems of *Low and High Pressure Steam Heating*, but the most useful is the *Vacuum System*, as in this the temperature of the steam does not rise above 212° F. Steam is led from a boiler to the radiators, which are similar to those on hot water systems. The steam, however, is reduced to atmospheric pressure by a reducing valve after leaving the boilers, and is condensed in the radiators, the condensed water passing through the exhaust pipe to a vacuum chamber worked by a vacuum pump, where a vacuum of 10 or 12 pounds is maintained. The radiators are fitted with valves to shut off the steam when required. The steam system of heating overcomes all the difficulties connected with the distribution of heat in large and irregular shaped buildings, and very uniform temperatures can be attained in all parts of such buildings. On the other hand, the heating surfaces are usually over a temperature of 200° F., and there is more tendency to the creation of overheated and stuffy atmospheres than with low pressure hot water systems.

Stuffy Atmospheres.—The exact cause of the stuffiness of atmosphere created when air is heated by contact with surfaces of over 200° F. has not been determined. It is not altogether a question of relative humidity, as the air of rooms warmed by radiant heat from open fire-places is often found to be of low relative humidity (less than 50), whilst it is fairly fresh to the sense of smell, and has no stuffy characteristic. The sensation of freshness, however, would appear to be due to three more or less co-existing conditions—namely, (1) absence of any odour due to organic matters or charred organic matters; (2) an air temperature not exceeding 65° F., when the external temperature is below the internal (room); and (3) slow movements of masses of air at slightly unequal temperatures, *i.e.*, non-stagnation.

Radiators.—The low pressure steam is specially suitable in high buildings, and where the apparatus is not in use the fact that the pipes are empty removes the risk of damage by frost. Wherever the low pressure hot water system is installed, radiators should be located under the windows, as these are the points at which the greatest loss of heat occurs. It is a good practice to construct radiators without feet, but carried on cast-iron brackets built into the wall; this facilitates cleaning.

Ventilating heat radiators are now largely used. They are fixed against an outer wall, so that fresh air can be conducted into the base of the radiator, and thence pass over the heating surface to escape into the room through a grating at the top of the radiator. By means of a valve, the communication with the outer air can be closed if desired. The ventilating effect, however, is slight, for the amount of fresh air capable of introduction in this way is small, unless there is some extractive force available to remove air from the radiator-heated room. Some form of hopper window ventilator is generally necessary in a radiator-heated room, which will allow the entry of comparatively large volumes of fresh air at the lower part of the windows directly above the radiator. The cold fresh air entering from the window then mixes with the warm air ascending from the radiator.

Electric radiators possess the advantages of yielding no products of combustion, and the heat is available immediately the current is turned on, but the cost of heating by this method is high at ordinary rates for current.

The fixing of the source of heat near the ceiling instead of near the floor has recently been advocated. The circulating fluid (steam or hot water) is carried in flow and return pipes around one or more sides of the room, about 1 to 2 feet below the ceiling. The advantage claimed is that, on the side of the room adjoining windows, these can be opened at the top, and the fresh air passing in over the pipe is warmed sufficiently to obviate all draughts, whilst circulating currents of air at slightly different temperatures are set up in the room, which prevent stagnation of atmosphere, and cause the healthful feeling of "moving air" currents.

Soft water is far preferable to hard water for use in boilers and hot water pipes. The deposit of lime salts from hard water gradually narrows the calibre of the pipes, which in time may become completely blocked. In boilers, the deposit forms a non-conducting lining, which obstructs the passage of heat to the water. When the fur lining is thick it may lead to an explosion, for the iron boiler plates become red hot from the heat of the fire. Should a crack in the fur suddenly form, the water, coming in contact with the red hot metal, is converted into steam with explosive violence. Another cause of explosion in kitchen boilers which are not connected with a hot water cistern, or are unprovided with a steam escape pipe, is the blocking of the

pipe which supplies cold water to the boiler. This occasionally happens after a hard frost, if the pipe is unprotected.

In adopting a scheme for heating purposes it is necessary to consider the heat required to raise and maintain the temperature of the air, and in addition to this the further quantity necessary to replace the heat lost through windows, etc.

Lighting.

The illumination of a room is a matter greatly affecting the comfort and, indirectly, the health of the occupants, and is of especial importance to eyesight in the case of factories, workshops, and schools, where the eyes are concentrated on small objects for many hours at a time.

Natural Light.

Sunlight is the greatest source of radiant energy on earth; and its importance, as a factor in the development and maintenance of health in the higher forms of animal and vegetable life, is well known. The human being quickly reflects its absence, more particularly in respect to the blood and the skin; and the pallid, feeble, and dull child taken from dark surroundings soon reacts to its beneficent influence. Indeed, light is in restorative and recuperative value almost the equal of fresh air. Its *modus operandi* on human beings is not, however, thoroughly understood. There is some experimental evidence from the lower animals that sunlight activates the metabolism of the body, increasing the oxidation processes, and quickening and enlivening the bodily functions. Its psycho-physical effects (more especially those of sunshine) are mentally exhilarating. Bright sunlight disperses depression of spirits and lack of energy; and so it has been well said that " where there is sun there is thought."

Hess and his fellow-workers have succeeded in rapidly curing rachitic infants, without any alteration of their diet, by exposing them for a few hours daily to sunlight, and even artificial sources of ultra-violet light have proved equally efficient. Since an equally quick result can be brought about by artificial sources of light in small, poorly ventilated rooms, the action of the air can be disregarded as a factor in this connection. It is believed by Hess that the remarkable seasonal incidence of rickets (greatly more prevalent in the winter and spring) is due to the seasonal

variation of sunlight. Possibly the exceptional incidence of rickets in some parts of Great Britain is explained by the deficiency of sunlight due to smoky atmospheres and bad housing.

The sun's rays contain elements which have other functions than the mere illumination of objects. Of the radiant energy from the sun, the invisible ultra-violet rays are the most powerful actinically; but we know little of their influence in nature, beyond the fact that the germicidal power of sunlight is largely due to its actinic power, which in this case probably operates in promoting oxidation. Such rays (intensified and cooled) have proved valuable in the treatment (heliotherapy) of various forms of skin disease. Sunshine has, in addition to its purifying effect on the atmosphere, a real value in ventilation, as it serves to set up convection currents. Thus, owing to the effects of the light, heat, and chemical influences of sunlight, many regenerative reactions take place; and it may be added that good light by disclosing dirt favours cleanliness, and serves as a deterrent to vermin.

This natural light is the best form of light for human vision; and in schools, factories, and workshops the importance of adequate lighting, both natural and artificial, cannot be exaggerated. Not only is good vision thus preserved, but better work is performed than is the case in poorly lighted rooms. A south-westerly aspect is the best for light; and we should give the sun far more consideration than it at present receives in the planning of our houses, in which entrance halls, pantries, bath, and box rooms often bask in the life-giving sunshine while living rooms have to go without. Again, the height of houses should always be in proportion to the distance of adjacent houses, in order to admit adequate sunlight to the lower rooms. In living rooms and bedrooms the window area should never be less than one-tenth of the floor area, and the windows should always extend nearly to the ceiling; in kitchens, sculleries, pantries, and nurseries the window area should be rather more; and in factories and workshops it should be even as great as one-fifth of the floor area, when fine work has to be done. (For the lighting of schoolrooms *vide* Chapter XI.)

A valuable aid to the lighting of dark interiors is the use in windows of prismatic glass, which bends the rays of light passing through it according to the angle at which the prisms are set. Reflecting mirrors set at an angle of 35° are also useful in increasing the lighting of dark rooms. Rays of light, so refracted

or reflected that they penetrate to the back of the room, should again be reflected by means of exceptionally light coloured walls. Frequent lime-whiting of the walls and ceilings of factories, workshops, etc., does much to improve the lighting, and this treatment should also be applied to any adjacent wall facing and near to the windows of insufficiently lighted rooms.

Artificial Lighting.

The most commonly employed method of obtaining an artificial illumination is the combustion of inflammable material producing a flame. Coal gas, petroleum and colza oils, and candles, are well-known examples of this form of illumination. In the electric light, on the other hand, there is no combustion, or only to a trifling extent; but light is emitted from a substance raised to a high temperature and a state of incandescence by the passage through it of an electric current.

The inflammable gases and vapours are chiefly compounds of carbon and hydrogen. When these inflammable vapours are heated to a sufficient temperature, the hydrogen combines with oxygen to form water vapour, and an intensely hot flame without luminosity is produced; the carbon particles, which are liberated in a state of very fine subdivision, are rendered incandescent by the heat of the hydrogen flame, and they combine with oxygen to form CO_2 and traces of CO. The luminosity, which is situated in the outer portion of the flame, is due to the incandescent carbon, whilst the inner portion—the hydrogen flame—is very hot, but almost non-luminous. The products of combustion are chiefly water vapour and carbonic acid. The light is very deficient in the blue and violet rays of the solar spectrum, and has therefore a yellow or orange colour. Hence the true colours of objects illuminated by a flame are not perceptible.

Coal Gas.—The principal illuminant of coal gas is heavy carburetted hydrogen or olefiant gas (C_2H_4). There are also present other hydro-carbons—*i.e.*, benzene, propylene, naphthalene—which are illuminants. The heavy hydro-carbons, if burned by themselves, would yield a smoky flame; but these are suitably diluted in coal gas by hydrogen, marsh gas or methane, and carbonic oxide, which together form over 90 per cent. of the coal gas.

Coal gas illumination was a great advance on the candle

illumination of a former period, but it has certain drawbacks. There is the danger of escape of gas in the houses from mains and pipes, forming, if the escape is large, explosive mixtures with the oxygen of the air; or if small, causing a serious pollution of the atmosphere. The products of combustion are injurious to health, and the sulphurous acid from the sulphur compounds in coal gas is destructive to books, furniture, and pictures. The combustion also heats the air and dries it; for although watery vapour is one of the products, the relative humidity of the air at the higher temperature is lowered. Finally, when the supply of gas and air is not regulated during combustion, the gas is wasted, the light is lessened, and unconsumed particles of carbon are given off which deposit as soot on adjacent cold surfaces.

The burners in common use are: (1) The *fish tail* or *union jet* which has a flat steatite top, slightly depressed in the centre, through which two small holes are bored in directions inclining towards one another from below upwards. The two streams of gas meet and produce the flat flame usually seen. (2) The *batwing* has a hemispherical steatite top, through which a vertical slit is cut for the gas to issue. The flame is flat and semicircular. The flames from these two burners require no chimneys, but are usually enclosed in globes to soften the light. (3) The *Argand* burner is a small ring or double-walled cylinder, pierced at the top with fine holes for the issue of the gas. The flame thus forms a hollow cylinder, and the air has free access both to its interior and exterior. The flame must be enclosed in a chimney, in order that the supply of air to it may be regulated.

The Argand burner has been improved by Silber, Sugg, and other manufacturers. These improvements are directed, first, to cause the issue of the gas at the lowest possible velocity, and, secondly, to divide and regulate the air supply both to the outside and inside of the flame, and to direct a part of it to the higher portions of the flame, where perfect oxidation of the carbon is most required. These improved Argands give a far better and steadier light for the same consumption of gas than the flat flame burners.

There are several *ventilating burners* in which the products of combustion of the flame are conducted through a flue to the external air, the heated and vitiated air from the top of the room or hall being also removed by ducts surrounding the flue.

The *sunlight* burners used in theatres and the *globe* light are examples of these.

The Welsbach *incandescent gas burner* now has a very extended use. It consists of a Bunsen burner, with a cap (mantle) of asbestos gauze material (rendered non-inflammable by chemical treatment with sulphate of zirconium) suspended in the non-luminous flame; the gauze mantle becomes incandescent and gives a brilliant light, far whiter and steadier than the ordinary gas flame. The flame should be enclosed in a chimney. Inverted incandescent burners are now commonly used, and require no chimney, but only a globe to reflect the light. The illuminating power is very high for the amount of gas consumed, and the heat given off is far less than with an ordinary gas flame. If such burners came into general use, a cheap form of gas containing no illuminants could be supplied; for heat and not light is required in the flame.

The Welsbach incandescent gas burner is, hygienically, by far the best form of lighting by coal gas.

In the *albo-carbon* light, the vapour of naphthalene is burnt in the coal gas, and a brilliant white light is produced. The naphthalene, which is solid at ordinary temperatures, is placed in a reservoir connected with the gas burner, and this reservoir must be heated by a small gas jet or by strips of metal extending from the flame. The vapour of naphthalene must not be allowed to escape into the air, as its odour is most offensive.

One cause of waste and imperfect combustion with flat flame burners is the constant alterations of pressure in the gas pipes and mains. At one period of the day the pressure may be less than one inch of water, whilst at another it may be 3 inches or more. Consequently the flat flame, which is steadily burning under the low pressure, at the high pressure is flaring and singing; more gas is issuing from the burner than can be perfectly burnt, and unconsumed carbon is given off from the flame to pollute the air and blacken everything around. To control these variations in pressure, gas governors or regulators are employed. In the larger form, the governor is fixed close to the meter, and controls the pressure throughout the house pipes; whilst a small form is made as part of each individual burner. The best kind of governor acts automatically; by the action of valves an increased pressure narrows the lumen of the channel through

which gas passes, and a diminished pressure widens it. Single burner governors are also found to answer fairly well.

Acetylene gas (C_2H_2), generated by the action of carbide of calcium on water ($CaC_2 + H_2O = CaO + C_2H_2$), furnishes a powerful white light; but its use is not unattended with danger, unless great care is exercised.

Petroleum Oils.—By the distillation of crude petroleum oil an oil suitable for burning in lamps—commonly called crystal oil or kerosene—is obtained. In the distillation, a volatile spirit (benzoline) and heavy oils, some of which are solid from containing paraffin, are also obtained, and are separated from the lamp oil.

Lamp oil contains the hydro-carbons previously mentioned, and gives off an inflammable vapour which at a certain temperature takes fire. This temperature varies for different specimens of oil, and is called the "flashing point."

A Select Committee appointed by Parliament attributed the chief danger from lamp explosions to cheap lamps of defective design, and they recommended that the flash point (Abel close test) should be raised from 73° F. (the limit defined by the Petroleum Act, 1879) to 100° F., that statutory powers should be created to enable the Secretary of State to issue orders affecting the manufacture and sale of lamps; and that information should be spread among the public as to the nature of petroleum and the management of lamps. In the suggestions issued by the London County Council, it is pointed out that the flashing point of ordinary petroleum oil is a little above 73° F., that the oil in the reservoirs of lamps is rarely heated above 100° F., and that the best safeguard against accident is therefore never to burn oil which has a flashing point of less than 100° F., which oil should be sold as cheaply as low flash oil. Lamps, too, should be strongly made, and kept thoroughly clean; especially should the reservoir and burner be strong; the latter should screw into the collar, and the base of the lamp should be broad and heavy. The wick should be soft, and should reach to the bottom of the reservoir, and just fill the wick tube; it should be frequently renewed, and before being put into a lamp it should be dried at a fire, and immediately soaked with oil. The reservoir should be filled with oil before the lamp is lit, and the burner made clean before lighting; the wick when lit should be partially turned down, and then gradually raised; the wick

should not, however, be left turned down; lamps that have no extinguishing apparatus should be put out by turning down the wick until there is only a small flickering flame, and a flat piece of metal should then be placed on the top of the chimney, so as to close it entirely; finally, cans or bottles used for oil should be free from water and dirt, and kept closed.

Owing to improvements in lamps, and to the prohibition of the sale of highly inflammable oils, the danger of explosion is now slight. Lamp explosions may occur when, from any cause, the vapour over the oil in the reservoir comes in contact with the flame of the lamp, as through defects in the lamp or by blowing down the chimney past an ill-fitting wick, etc. But the best duplex lamps (the Defries and other safety lamps) are now sold with extinguishers, and with an ingenious arrangement by which, if the lamp is overturned, the flame is immediately extinguished.

Lamp accidents generally appear to arise from the use of cheap lamps of defective design, leading to a leakage of oil through imperfect connections and fittings. The oil may thus become ignited. Sometimes the lamp is upset from its instability, or broken owing to the fragile character of the reservoirs.

The "Petrolite" lamp is a safe lamp of high candle-power. In this lamp the petrol is absorbed by a block of highly absorbent stone, and the petrol vapour, being made to mix with air, furnishes a hot flame, which, playing upon a mantle, produces a brilliant incandescent light. In the event of the lamp being upset the flame is immediately extinguished.

The Kitson light has been used successfully for the purpose of public street lighting. This light is obtained by the automatic vaporization of petroleum oil, the mixture of air with this oil by injection, and the impingement of the flame upon a specially made mantle. The diffusive power of this light exceeds both the electric arc light and the incandescent gaslight, it is cheaper than either, and the roads have not to be taken up—as when electric light or gaslight is employed.

Colza oil does not give off any inflammable vapour, but it is much dearer than kerosene, and the illuminating power is less. Colza lamps require more care in trimming than kerosene lamps. Kerosene, like coal gas, gives off sulphurous acid when burned, but colza oil does not.

Candles, especially the cheaper kinds, give off much unconsumed carbon, by reason of their low melting point admitting of

volatile products being given off before the fats reach the flame and are properly consumed.

Electric Light.—The electric light presents the following advantages over coal gas, oil, and candles: There is no consumption of oxygen, there are no products of combustion to pollute the air, and the heat produced is relatively slight. The light of the arc light is not yellow, but white. It precisely resembles solar light in being rich in the violet and the ultra-violet rays. Plants grow and flower, and fruit ripens, when exposed to this light, just as they do in the sunlight; whilst photographs can be taken as easily by the arc electric light as by daylight.

The electric current can be produced by batteries, accumulators, and dynamo machines, and is conveyed in copper wires to the spots where illumination is required.

In the arc light, which is suitable for lighting streets, squares, and large halls and buildings, the illumination is produced by the passage of the current through two carbon rods brought into close apposition. The resistance offered to the passage of the current across the space intervening between the points of the carbon rods creates sufficient heat to cause the carbon points to become brilliantly incandescent. The light is extremely dazzling, and is productive of injurious effects on the eyes of those who are much exposed to its influence.

The incandescent lamps are best suited for domestic use. In these the current is passed through a loop of filamentous carbon enclosed in a small glass globe exhausted of air, or filled with some gas (such as nitrogen) which does not support combustion. The resistance offered by the carbon to the passage of the current raises it to a white heat.

Metallic filaments are now largely used instead of carbon. These metallic filament lamps give a far more powerful and whiter light with less current than do the carbon lamps.

CHAPTER V

SOILS AND BUILDING SITES

The health of a locality is often influenced by the nature of the soil on which the houses are built; and it has been truly said that if the site is unhealthy, the dwelling cannot be made healthy. It is generally believed that the most porous soils—the gravels and sands—are the healthiest, because they are the driest, and this view is in the main correct; but owing to their porosity they are readily polluted by leaky drains and cesspools.

The porous or permeable soils—the loose sands and gravels and the sandstones—are capable of holding considerable volumes of air or water. Even the impermeable rocks—the granites and metamorphic rocks, the dense clays and hard limestones and dolomite—are not wholly unabsorbent, but comparatively speaking they may be looked upon as impermeable. Between these and the porous sands and gravels are all stages of gradation. The surface soils which usually lie upon the denser kinds of rocks, of which they are to a considerable extent the weathered fragments, are always more or less porous. The interstices or interspaces between the particles of the porous soils are necessarily occupied by air (ground air), or at a varying depth by water (ground water). When there is air as well as water between the interstices, the water is nothing more than "ground moisture," but when the interstices are completely filled with water, then the "ground water" has been reached. The ground water is derived from the rain which percolates the soil until it reaches an impervious stratum which prevents it penetrating any further. Above the level of this subterranean water the interstices of the soil are mainly filled with air.

The depth at which the ground water will be reached in any soil depends on a variety of circumstances—the elevation of the district and its surroundings, the depth of the impermeable stratum from the surface, and the ease with which the underground water reaches its natural outlet in spring, river, or sea.

In the low-lying plains and valleys the underground water is not, as a rule, far from the surface of the earth. Its level is not constant, as we have seen in the chapter on Water (p. 19), but is always changing. After heavy rainfall the level may rise; and there is usually a periodic rise, commencing in the late autumn, due as explained before to the increased percolation of rain-water through the autumn and winter, and its diminution through the drier spring and summer months. The lateral movement of the ground water is generally towards the nearest watercourses, the sea, wells, fissures in rocks, shafts of coal-mines, etc.

The rise and fall of the ground water cause corresponding movements in the ground air which lies above it. As the ground water rises, it occupies the space formerly occupied by the ground air, and the latter is slowly expelled from the surface of the earth: as the ground water sinks, air is drawn in to occupy its place, to be again expelled when the water rises. There are other factors influencing the movements of the ground air which have no effect on those of the ground water. The principal of these are alterations in barometrical pressure, sudden variations in temperature, and the perflating action of the wind.

It is thus seen that the porous surface layers of the earth act as a sort of lung, slowly taking air in and slowly expelling it again. This action is no doubt greatly increased on the small surface of ground covered by a house. In winter, when the adjacent surface of ground may become ice-locked, the heat of the building and the aspirating action of fires must tend to draw air in large volumes through the soil beneath the dwelling, unless the site is covered with an impenetrable layer of asphalt or cement concrete.

The ground air is generally moist and always impure. The amount of moisture depends on the proximity of the ground water to the surface of the soil; if this is but a few feet from the surface, the ground air is saturated with moisture; if at great depths, the moisture is not excessive. But the ground near the surface of the earth in most parts of the world is damp, even after a prolonged drought, owing to capillary attraction and evaporation from the surface of the ground water. The impurity of the ground air is due to the decomposition of the various organic matters which are washed into the soil by the rain, or which are naturally present in some marshy soils. These latter are usually of vegetable origin. The impurity of

the ground air even in virgin or natural soils is shown by a great diminution in oxygen and an enormous increase in carbonic acid. In the neighbourhood of houses, however, the foulness of the ground air is often due to animal contaminations, and these may be of the most dangerous description. Leaking cesspools, sewers and drains allow animal filth, and possibly infected excretions, to pollute the water and air in the soil; graveyards and cemeteries permit decomposing animal bodies to exercise a similar pollution: whilst the organic effluvia arising from *made* soils—soils formed of old deposits of house refuse and dry rubbish—seriously imperil the health of the inmates of the houses built over them.

The organic matters, whether of vegetable or animal origin, are decomposed in the soil by micro-organisms. These organisms grow in the presence of such food material, breaking it up into simpler combinations—carbonic acid, ammonia, and water—and thus by the processes of fermentation and putrefaction exert a purifying action, and at the same time convert the complex organic bodies into products best fitted to be assimilated by the growing vegetation. The presence of oxygen, warmth, and moisture is essential to the proper carrying out of these processes. The oxygen is present in the ground air, the moisture is derived from the ground water, and the temperature of the soil is usually suitable, except during long frosts or in very cold climates.

It is thus seen that surface soil acts as a vast natural laboratory for the purification and utilization of effete animal and vegetable matters.

The draining of damp soils, so as to permanently lower the level of the subsoil water, is a measure much needed in the interests of health. In the first place, it is desirable to avoid great fluctuations in the level of the ground water; and this can, to a certain extent, be accomplished by subsoil drainage, which at once carries off the water when it rises to the level at which the drains are laid. When the subsoil water rises, it forces the ground air before it and out of the soil; not only this, but it causes, when it arrives within a few feet of the surface, a dampness of the atmospheric air and, by evaporation, a cooling of the air. The moisture ascends by capillary attraction into the walls of houses, to be subsequently evaporated from the surfaces of the internal walls; in this evaporation heat is absorbed from surrounding objects, and the air of a house with damp walls is not only moist, but cold.

This condition of dampness in the site and air of a house is one credited by universal experience with the production of rheumatism, catarrh, neuralgia, and affections of a bronchial and pulmonary nature, and is probably a predisposing factor to diphtheria, measles, and whooping-cough.

The researches of Dr. Bowditch, of Boston, U.S.A., and of Dr. Buchanan in this country, have conclusively shown that there is an intimate connection between moisture of soil and phthisis. Such diseases were shown by Dr. Buchanan to be much less fatal in certain English towns after these towns had been sewered and the soil consequently drained, than they had been previously to the construction of the sewer works. Where the drying of the subsoil was considerable, the deaths from phthisis were reduced to two-thirds, or even one-half, of what they had previously been.

Professor Pettenkofer has shown a relation between the height of the ground water and epidemic outbreaks of enteric fever in Munich; and he demonstrated that when the water in the wells was at its lowest level, especially after a rapid fall succeeding an unusually high level, the disease was most prevalent in that city. Munich is built on a porous sandy soil, at that time riddled with cesspools, of which the contents rapidly soaked into the surrounding soil; so that it is conceivable that, after heavy rainfall, liquid cesspool filth would be carried into the wells, and an outbreak of enteric fever might result two or three weeks after the specific pollution of the drinking water, and when the level of the ground water had fallen.

In this country, however, no invariable relation has been found to exist between the onset of enteric fever epidemics and lower level of ground water.

But in considering this subject, it must not be forgotten that there are other factors, such as temperature, condition of the soil as regards moisture and pollution, etc., which may have a more direct bearing on health conditions than the level of the ground water. The right view appears to be that fluctuations of level are of but little consequence in themselves, but that by favouring pollution of water in wells, or by forcing impure ground air into houses, they may exercise a considerable influence on health.

Pettenkofer has also recorded the occasional coincidence of cholera outbreaks with a low state of the ground water. Epidemic

diarrhœa occurring in summer and autumn has also been shown to be related to certain soil conditions, and the prevalence of yellow fever is also generally held to be influenced by soil, which being retentive of surface moisture favours the breeding of mosquitoes.

The connection between malaria and damp marshy soils capable of holding stagnant water—the breeding grounds of the mosquito (*Anopheles*)—is more firmly established. In many instances malarious districts have been rendered healthy by subsoil drainage or by tree planting. In hot climates trees and vegetation abstract large quantities of water from the soil, and this is evaporated from their green leaves. It has been calculated that an oak-tree evaporates eight and a half times the rainfall over the area it covers, whilst the *Eucalyptus globulus* absorbs and evaporates eleven times this amount. The latter tree has been extensively planted in many malarious districts, with the effect of rendering them more healthy; for the soil has been dried by permanently lowering the level of the subsoil water, and the moisture factor being withdrawn, the mosquitoes are no longer provided with an environment favourable to their propagation. It must be remembered also that moisture favours decomposition of putrefiable material; therefore a dry soil is cleaner, and the ground air is purer, than in the case of a damp one.

In very damp, marshy districts it is advisable that houses should be raised above the ground on arches open to the air; or, in the case of wooden houses, on piles. Moist ground immediately around the site of the house should even then be drained and filled in, and the surface covered with grass kept closely cut. Excessive vegetation should be cleared away and burnt.

Low-lying alluvial tracts are not desirable sites for residences, for the ground water is either very near the surface, or the ground is water-logged for many months of the year; and the site is damp, subject to fogs, and affords an unreliable foundation for buildings. When an alluvial site is on the borders of a river, it is liable to flooding, and it becomes extremely difficult to secure dry basements. There is, moreover, great difficulty in providing efficient drainage for the sewage of the house, especially where houses have basements.

From the above remarks it follows that for the choice of a site for a house, a dry, fairly open and sunny situation and a pure, dry and porous soil are desirable, in an elevated position and on a gentle slope favouring natural drainage both on the

surface and in the subsoil. Valleys lying in the direction of the prevalent winds are drier and therefore more healthy than those lying in other directions. In cold and temperate climates, sands and gravels, if of considerable depth, and not water-logged by reason of a low situation or underlying clay permitting ground water to rest upon it, are the healthiest, because the warmest (most absorbent of heat) and the driest. Gravel in patches has sometimes a clayey or loamy matrix, and may thus be itself retentive of water. Clayey soils are cold, because little absorbent of heat; they are also damp from the retention of moisture, and therefore not so healthy as the more permeable soils. The disadvantages of living on clay are materially reduced by elevation with sufficient surface falls to favour good surface drainage. Chalk is usually dry, but, being little absorbent of heat, is cold. Generally speaking, soils may be classified as follows, in the order of their healthiness:—Gravel, sand, sandstone, chalk, rocks (granite, clay-slate, limestone), loam and stiff clay, alluvial land (low-lying), made soil. In hot climates sands are excessively hot, unless covered with herbage, which protects from the sun's rays and cools the air by evaporation of moisture. Trees by favouring the stagnation of air tend to check evaporation from the ground, and thus favour dampness. They may be utilized, at a sufficient distance from the house, for sheltering from the north and east winds.

In towns, *made soils*—which result from the filling in with household refuse and other rubbish of low-lying sites or excavations made for the purpose of removing the virgin gravel, etc.—should be avoided.

If the soil is damp, the entire site below the foundations should be drained by laying unglazed agricultural pipes in trenches filled in above with pebbly gravel. This allows free percolation of water into the pipes, through the porous material of which they are constructed and between their ends, which are laid in apposition but not jointed. The subsoil drains should not be connected with any soil drain, sewer, or cesspool, but should discharge, if possible, into a ditch or stream. Where this is not possible, the subsoil drain may be connected with a house drain or sewer after proper disconnection has been practised, as for house drains (*vide* page 100). In open soils, such as sands, a single drain will lower the level of the ground water over a considerable area, whereas in stiff close soils numerous drains are necessary. The ground water

should preferably not reach to within 10 feet of the surface of any site on which a dwelling is to be erected.

To prevent the entrance of ground air and moisture, the entire site of the house, within the external walls, should be covered with a layer of cement concrete, 6 inches thick, rammed solid; and the surface thus formed should be grouted over with cement. In large town houses with basement floors below the street level, the cemented surface when asphalted, tiled, or paved with solid wood-block flooring may conveniently form the finished flooring; being free from cracks and crevices, it can afford no lodgment for cockroaches or other vermin, which so frequently infest the lower storeys.

In houses without cellars, more especially where the site is not concreted over, the lower floors should be raised 2 feet above the surface of the ground, and the intervening space should be well ventilated through air grids or air bricks in the external walls.

Great care must be taken that the excavations for the house foundations are protected from the access of water by proper drainage where necessary, otherwise they serve to store moisture and occasion serious dampness in basements. If the building is on sloping ground, it should be well protected from moisture on the side towards which the surface waters flow. The building should be erected on a uniform bed—not partly on gravel and partly on clay, for instance, as there would then be unequal resistance to the superincumbent pressure. A chalk foundation should be first well tested, as cavities or pipes therein may lead to subsidence. Clay slopes are undesirable sites, because the clay may shrink and crack after a prolonged drought, or swell and soften after much rain, and thus injure the building.

A wall built of ordinary building bricks and mortar is very porous, and capable of absorbing large quantities of water. Each brick can hold about 16 ounces of water.

To obviate damp from the ground rising in the brick walls, a horizontal damp-proof course of slates bedded in cement, a ½-inch layer of asphalt, or slabs of perforated glazed stoneware, should be inserted in the wall, slightly above the level of the ground adjoining. The stoneware slabs answer a double purpose; they are not only damp-proof, but the perforations afford an air passage through the wall, and ventilate the space under the flooring—a very necessary precaution to prevent dry rot in timbers and joists.

Damp-proof courses may even be inserted in the walls of old buildings, by removing a course of bricks piecemeal, after underpinning the walls, and then inserting air bricks in sections.

The external house walls, when these pass below the surface of the ground, must be separated from the moist earth by an "open" area extending upwards from the footings or foundation. Where space will not permit of an open area, a "dry" area should be formed (fig. 36).

This is merely an area a few inches wide, to prevent the moist earth coming in contact with the wall, which is carried up well above the surface of the ground, and is covered at the top, or

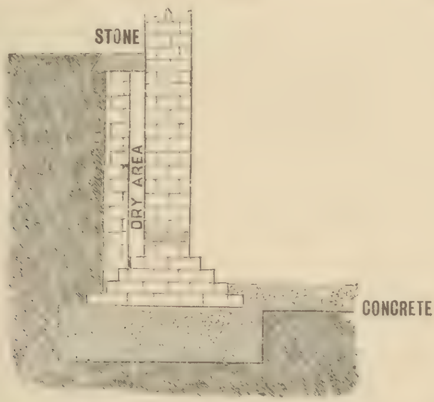


FIG. 36.—HOUSE FOUNDATION WITH DAMP-PROOF COURSE IN WALL AND DRY AREA.

a double (cavity) wall may be formed below the ground level so as to enclose a narrow vertical air space. This arrangement necessitates two damp-proof courses—the lower just above the footings, and the upper across the outer portion of the cavity wall slightly above the ground level. These provisions are necessary to prevent damp cellars and basements.

In very exposed situations the outer walls of houses are liable to become damp from driving rain. The usual remedies consist in covering the walls with slates or glazed tiles, set in cement, or coating the brickwork with Portland cement, mixed with "pudlo," which, being impervious to moisture, answers extremely well.

House walls constructed of soft porous bricks jointed with bad mortar are especially liable to become damp from driving rain. If both bricks and mortar are soft and rotten, the wall should

be coated with cement; if the bricks are sound, but the mortar decayed, the wall should be repointed with good cement. Good lime mortar should contain one part of recently burnt lime to three parts of sand. Cement mortar consists of one part of cement to four of sand.

Sometimes in new houses the wall-papers are stained from temporary dampness, which is due to the evaporation of the water in the newbricks and mortar (" building water ").

Another common cause of damp walls is defective gutters to the roof, or broken or otherwise damaged rain-water pipes. In both these cases water drips down the outer walls, and, soaking through the bricks and mortar, causes a serious dampness.

In most towns the local authorities now compel house owners to pave the ground immediately around dwellings. The best material for yard-paving is cement concrete, the Portland cement being first well dried and then thoroughly mixed with clean sharp sand. Asphalt also makes a good paving. Other materials used are blue glazed Staffordshire bricks and York flagstones, but in these cases a good hard and smooth bottom of concrete should first be laid.

There is probably some relation existing between the sanitary condition of streets in urban districts and the prevalence of summer diarrhœa. The desirability, from a public health standpoint, of perfectly sanitary roads is now recognized. The sanitary condition of streets depends not merely upon the use made of them, but also upon the materials of which they are constructed, and the manner in which they are kept, as regards the frequent removal of slop and dust.

A perfectly good road should have a firm, dry foundation, with a hard, tough, and compact surface, the latter being neither too flat to allow water to stand, nor too convex to inconvenience traffic.

The substitution of mechanical power for horse traction would be a great sanitary advancement, and in the matter of street cleansing would effect a great saving of expense. The usual method of bringing trade refuse out into the streets, and the general littering which results, is a practice which ought not to be allowed. In large urban communities a considerable proportion of the population spend the major part of the day in the streets, and their houses practically abut upon them. The necessity, therefore, of keeping the streets as wholesome as

possible by guarding them from all avoidable animal and vegetable pollution by frequent scavenging is obvious, and makes itself specially felt in the hot weather, when the odours given off from badly scavenged streets are most marked, and the suspended dust (consisting of powdered horse-dung, etc.) is highly unpleasant and irritating to the eyes and throat. Frequent flushing by water vans or by hose has possibly some effect in reducing the prevalence of summer diarrhœa.

The chief kinds of road paving are macadam, granite setts, wood, and asphalt. Macadam creates by far the most mud and dirt, and is therefore expensive to maintain and cleanse; it is noisy and very absorbent. Constant watering in dry weather, and cleansing of the surface at all times, are absolutely necessary to maintain macadam roads in good condition.

Granite setts furnish a most enduring pavement, easily and cheaply repaired and cleansed, and practically non-absorbent. The great objection to this form of pavement is the noise arising from the wheels of the vehicles and the iron shoes of the horses striking upon it. The noise can be diminished by running the joints with asphaltic composition instead of the ordinary Portland cement grouting.

In Durax paving, the setts are cubes of Swedish granite, but they are small (about 2-inch cubes), with plain facets, and are laid in regular formations in asphaltic composition, the result being a very durable and not very noisy road, as it is comparatively smooth on the surface.

Wood paving is the most expensive, but possesses the following advantages: it is comparatively noiseless; it is clean, and creates no mud of itself until it is worn; cleansing is easy, when not much worn; and, though slippery at times, a fall does not hurt a horse like a fall on an asphalt or macadam road. The disadvantage is its capacity for absorption, with the giving off of offensive odours during the hot, dry season; but this is in some measure obviated by the use of hard woods, creosoted under pressure and jointed with impervious material.

Asphalt is the most sanitary paving, being smooth, impermeable, jointless, and most durable. It is cleansed, swept, and flushed more easily than any other kind of paving, and is admirably adapted for all classes of town roads and streets which are level, or have only very slight gradients. Its chief disadvantage is that it is slippery when first damped with rain, and

that horses fall very heavily on it. It is doubtful, however, if it is more slippery than wood under similar circumstances. For motor traffic and for pedestrians asphalt forms an ideal paving material.

For the surface treatment of roads for the purpose of dust laying, the methods which are employed are watering, tarring, oil tarring, and treatment with certain trade preparations containing tar oils, etc., and calcium chloride. It is generally accepted that coal tar should be applied hot, and the treated surface covered at once with fine grit. Well-laid macadamized roads treated once a year by spraying with hot tar, which is at once covered with fine granite chips or other gritty material, have been found to answer admirably. The surface is less broken up by road traffic, and there is much less dust in dry weather; in wet weather the road is prevented from getting water-logged in its foundations, and the general life of the roadway is much increased. Such roads are generally known as "Tar-Mac" roads.

Oil tar is the by-product of the manufacture of gas from oil, and it is necessary to apply about four dressings during the six summer months. It may be applied by means of the ordinary water-cart, manual labour being utilized to work it into the road. A solution of calcium chloride may be applied by means of the ordinary water-cart, the calcium chloride, by taking up moisture from the atmosphere, tending to keep the road surface slightly moist.

The Dwelling—General Considerations.

With regard to aspect in this country, north and north-eastern aspects are cold, whilst southern are warm; north-western and south-western are exposed to boisterous winds, and the latter generally to driving rains; the south-easterly aspect is generally dry and mild, and it is well to select this for the living-rooms and principal bedrooms of a house. Sunshine should be capable of entering every living-room at some period of the day. The provision of bay windows will help to secure this desideratum. The sufficient lighting of every room is most important. Gwilt's rule that there should be 1 square foot of glass to every 100 cubic feet of room-space is probably rather an under-estimate of the requirement in towns; on the other hand, excessive window provision makes a room very warm in summer and cold in winter.

All staircases, passages, and corridors should be well lighted and ventilated direct from the outside air.

Bedrooms should have, where practicable, an east or south-east aspect, so as to get the morning sun; they should have plenty of window area and an open fire-place.

Too little attention is often given to the situation of the larder, and it is frequently found in a most undesirable position—badly lighted, badly ventilated, the window opening just above the dust bin, and one lath and plaster wall separating it from a water-closet. The larder should face north for coolness, and have provision for a through current of fresh, pure air; the window should be protected with perforated zinc to exclude insects.

All chimneys should be kept as much as possible together, and protected from cold so as to favour upward draught.

The most sanitary wall covering for water-closets, bathrooms, and sculleries is glazed tiles, or the walls may be cemented and painted; in either case they can be easily and frequently cleansed. For bedrooms distempering is to be preferred to wall-paper. If in the sitting-rooms wall-paper is employed, one with a smooth varnished surface should be chosen in preference to an uncleanly, absorbent flock paper.

As to the floors, the ordinary floor boarding supported on floor joists, placed 1 foot apart, and leaving an open space some inches in depth between the floor surfaces and the concrete foundation or the ceiling of the room below, has little to recommend it. The space beneath the floor becomes a receptacle for dirt, which gets through the cracks between the floor boards. Whenever such a floor is laid down it should be made with grooved and tongued, or ploughed and tongued boarding, so as to insure the boards being tight-fitting. But it is far preferable that "solid floors" should be constructed by laying the floor joists side by side and nailing the floor boarding to the solid upper surface of the joists.

For large buildings fire-proof flooring formed of coke-breeze and cement laid on steel joists is most desirable. The floor boards should be nailed to the fire-proof material.

Glazed tiles and bricks form satisfactory floors for water-closets, lavatories, bathrooms, sculleries, and larders. The best floor covering for the rest of the house is hard wood, such as oak well fitted, beeswaxed, and polished; or hard, well seasoned deal, stained and well varnished. Parquet flooring insures a uniform and impervious surface.

For roofing, some non-absorbent material is to be preferred. Roofs of thatch and wood are liable to be damp and to harbour insects, and their inflammability is a source of danger; but thatching with reeds from salt marshes is far less inflammable. Slates and tiles are good materials; the former are light, but, being good conductors of heat, are cold in winter and hot in summer, whereas the latter, though heavy, are warmer in winter and cooler in summer. Lead, zinc, and copper have all been used for roofing; like slates, they are good conductors of heat, and impervious.

In house furnishing, woolly and fluffy articles of decoration, heavy draperies, fittings and ornaments, which will harbour dust and render it difficult of removal, should be avoided, and carpets should not be made to cover the whole floor and be nailed to it, but should be laid down as squares which admit of easy removal for cleansing purposes.

Walls are generally built of brick, stone, timber, or concrete. The materials used in building should be as compact and as impermeable as possible; all bricks should be hard and as little absorbent of moisture as practicable, all wood well seasoned, and the plaster impermeable.

Moisture condenses upon the inner surfaces of external walls, because those surfaces are cold; and a wall is cold because it is too good a conductor of heat. The only remedy is to make the wall a bad conductor of heat by thickening it, by a careful choice of material, or by the provision of a cavity or cavities in the thickness of the wall.

"Light construction" materials are now being extensively used for certain classes of building, and especially for structures designed for temporary occupation. The weight of the building is carried on steel piers and steel framing, the interspaces being filled with hollow slabs of stoneware material, which form a wall at once impervious to moisture and highly non-conductive. The cost of such a structure is considerably less than if it were brick-built. Buildings constructed of "reinforced concrete"—*i.e.*, concrete strengthened by steel rods and ties introduced in its substance—are also strong and cheap. A notable example of this form of construction may be seen in the new General Post-Office at St. Martin's-le-Grand, London.

In the economical construction of cottage homes, the following considerations appear to meet with general approval:—

The number of houses should range from twelve to twenty per acre.

There should be a paved space at the back of the house, and a small shed is desirable upon this space.

The internal accommodation should generally include living-room, scullery, bath-room, three bedrooms.

The varying bedroom needs of tenants is provided for in block dwellings in towns, three being most generally provided, but some dwellings contain one, two, and even four bedrooms.

The living-room should vary from 150 to 190 superficial feet; one of the bedrooms should be 120 to 130 square feet, and the second and third 80 to 100 feet. The rooms should be at least 8 feet in height.

The bath may be placed in the scullery, which should adjoin the kitchen.

There are advantages in combining the three requirements of heating, cooking, and hot water supply from a single fire.

From the construction standpoint, the ground-floors should be of concrete; for walls the most satisfactory result, however, has been obtained by utilizing concrete, in 2-inch or 2½-inch blocks, with a 2-inch cavity between, secured with galvanized iron wall ties, the outer block being made with a dense aggregate, and the inner block with a more porous material. This construction has been most satisfactory in one-storey buildings. If utilized in two-storey buildings, the thickness must be increased, or piers introduced where necessary.

Lath and plaster partitions should be avoided and replaced by slabs, concrete, or half-brick; for roofs, timber with a covering of artificial slates, with felt or Willesden paper placed under to render the houses warmer.

Communal steam heating from a central station has been given considerable attention, but unless exhaust steam from a factory can be utilized the method is not likely to be economical, because, in spite of every precaution, the loss of heat in the pipes between the houses is considerable.

Where the houses are in small groups so that sewage has to be dealt with in small quantities, it may often be disposed of on the surface of land in the vicinity, where the levels and the nature of the soil, etc., permit. In such cases a small tank or catch-pit, with a screen or scumboard, should be provided, and the solids removed and buried, and the irrigation regularly attended to. A system of subsoil irrigation or soak-away pits cannot be recommended or allowed.

CHAPTER VI

CLIMATE AND METEOROLOGY

Climate.

The human body possesses marvellous powers of adaptability to the varying external conditions occasioned by changes of climate and season, and the transition from cold to heat, dryness to humidity, and vice versa. The normal temperature of the body is sustained, and the bodily functions are properly performed, under all the varying conditions of climate and season to be met with in the habitable globe.

In hot climates, where the temperature of the air approaches, or even exceeds at times, the temperature of the blood, there is little call made upon the heat-producing powers of the body. As less food is required, metabolism is decreased; the urea of the urine and the respiratory carbonic acid are lessened in amount; the digestive and assimilative powers are lessened; and oxygenation of the blood is diminished, because the number of respirations is decreased and the heated air contains less oxygen in a cubic foot than cold air. At the same time great heat, although compatible with health, is enervating; for the perfection of bodily activity can only be obtained when tissue changes are rapid. In hot climates the skin is extremely active, and the secretion of sweat enormously increased. This means great evaporation from the surface and cooling of the blood, with the result that the body temperature is maintained at its normal level.

At high atmospheric temperatures the body loses little or no heat by radiation, while the loss by evaporation is considerable; whereas at low atmospheric temperatures, while the heat lost by radiation is considerable, that lost by evaporation is very small indeed.

The effects of cold are exactly the reverse to those of heat. To maintain the temperature of the body, tissue metamorphosis

must be rapid; food, and especially carbonaceous food, must be taken in large quantities; oxygenation of the blood and elimination of CO_2 are increased; the skin functions are reduced to a minimum, while the excretion of urine increases, and but little blood reaching the surface, surface cooling is obviated; whilst the rapid tissue changes permit of great bodily and mental activity being shown.

Great humidity of the air causes lessened evaporation from the lungs and skin. For the air, being saturated, or nearly so, with moisture, has little drying power, and the moisture from the skin and lungs is with difficulty evaporated. The evaporation of moisture, by which much heat is rendered latent, is one of the chief means of cooling the body. Consequently, when the air is hot and very moist, the humidity tends to increase the effects of the heat; the blood is with difficulty kept at its proper temperature; and all the disagreeable results of the high temperature are intensified. Moreover, the humidity of the air affects the climate of a place by hindering the terrestrial radiation of heat. It is under such conditions that "heat-stroke" is apt to occur.

For healthy people in temperate climates, the pleasantest degree of humidity is about 75 per cent. of saturation. This figure is a climatic average for the year. The relative humidity of the outer air varies greatly from season to season, from day to day, and even from hour to hour, and there is no evidence that atmospheres of high or low relative humidity are *per se* unhealthy. At night and during rain the relative humidity is high, the atmosphere being often nearly or quite saturated with watery vapour, whilst a warm sun and a dry wind will cause a drop in the relative humidity from 90 to 40, and that within the space of an hour or two. It is evident that, in Nature, the changes in relative humidity are extensive and rapid; and it seems probable that the human body, under normal conditions of health is capable of adapting itself as readily to these hygrometric changes as it is to the varying temperatures of an uncertain and variable climate. Some of the more rapid fluctuations of relative humidity are probably attributable to passing intervals of sunshine

When atmospheric humidity is very high perspiration is hindered, skin functions are impaired, and there is a diminution of the excretion of water vapour in respiration. This throws

additional work on the kidneys, of which renal patients may be acutely conscious, and the discomfort is enhanced when the temperature is low. The pains from rheumatic arthritis and neuritis are aggravated; and epithelial accumulations, such as corns and scars, being somewhat hygroscopic, swell under the action of the humidity, often causing increased tenderness and pain. The cold dry east wind, which is invigorating to a robust constitution, owes its searching qualities to the fact that its dryness enhances evaporation from the skin, and, as heat is absorbed in the process of the transformation of water into vapour, a disagreeable feeling of cold is caused.

The effect of movement of air (winds) on evaporation is very great. In cold weather a chilly wind, if dry, increases the evaporation, and also lowers the temperature of the body by the impact of its cold particles, which absorb the heat of the body and then pass away to be replaced by more cold air. The skin becomes dry and chapped, and the lungs are irritated. In hot climates a dry, hot wind increases the evaporation enormously.

The warm and moist south-west winds in the British Isles are mild and relaxing, while the drier and colder east and north winds are bracing.

A bracing wind cools the skin, tones up the muscles of the body, voluntary and involuntary, and impels us to take exercise to keep warm. The augmented metabolism leads to increased oxidation of food-stuffs, deeper ventilation of the lungs, more efficient massage of the belly organs by the deeper breathing and muscular exercise, better appetite, more perfect digestion and less bacterial decomposition in the bowels, more vigorous circulation of the blood, thus in every way promoting health. Physiological research has shown that it is not the chemical purity, but the physical conditions of the atmosphere, which act so potently upon us.

At high altitudes the air is rarefied, and the pressure of the atmosphere is diminished. The other conditions met with in mountain climates, as contrasted with those of plains, are: (1) Greater movement of air—strong winds are very prevalent; (2) lessened humidity; (3) increased sunlight; (4) great freedom of the air from suspended matter—mineral and organic; (5) a small amount of ozone in the air; (6) a lowered temperature generally; but as the soil is rapidly heated by the sun, the days

in summer may be warm, whilst the rapid radiation of heat, as soon as the sun sets, causes sudden cooling and a very low temperature at night. Temperature decreases with altitude to the extent of about 1° F. to every 300 feet of ascent.

Although the weight of oxygen in a cubic foot of air is decreased at high altitudes,[1] the oxygenation of the blood is increased, for the respirations are more frequent and have greater depth; and after a period of residence the lungs somewhat expand and the capacity of the chest is found to be increased in all its measurements, together with increased power of expansion and contraction. The action of the heart is also increased, and tissue change is stimulated by the low temperature and the dryness of the air, leading to improved digestion, assimilation, and excretion, with increased bodily activity.

These effects of residence at a high altitude, together with the freedom of the air from dust and germs, have led to the treatment of cases of phthisis at mountain resorts, with often the most beneficial results. The cases most benefited are those in an early stage without much congestion or bronchitis, which might be aggravated by the cold dry air. It is advisable that spots should be chosen which are sheltered from cold winds; and those popular resorts, where many phthisical persons are crowded together in hotels and boarding houses without proper precautions being taken, should be avoided. As much time as possible should be spent in the open air.

A mountainous district in proximity to the sea is liable to excessive rainfall. The moist currents of air blowing in from the sea are chilled by striking against the mountain chain; clouds are formed, and some of the moisture, no longer able to be held as invisible vapour at the lower temperature, is deposited as rain, snow, or sleet, according to the temperature and season of the year. If the mountains are in the centre of a continent far removed from the sea, the rainfall may not be great. The excess of moisture in the ocean currents will already have been deposited before reaching the hills; and in these situations a mountain climate without the drawback of excessive rainfall may be obtained, suitable for the requirements of consumptives and

[1] The weight of oxygen in a cubic foot of air is diminished in proportion to the diminution of pressure; thus, if the barometer stands at 20 inches, the 130·4 grains of oxygen present in a cubic foot of dry air at 30 inches of mercury and 32° F. is reduced to $\frac{20}{30}$ of 130·4 = 86·9 grains only.

invalids. The westerly winds which blow over the Rocky Mountains deposit most of their moisture on the western sides of the range, and on the eastern slopes the climate is comparatively dry and cold.

It is a well-known fact that travellers ascending to high altitudes suffer from a series of symptoms, varying in different individuals, but generally comprising shortness of breath, palpitation, prostration, and a disinclination for exertion; at still greater heights the symptoms may be more severe, and may include loss of appetite, nausea or vomiting, cramps, drowsiness, giddiness, a throbbing headache, loss of mental power, and great bodily exhaustion; occasionally there are hæmorrhages from the nose, eyes, or mouth. All these symptoms are aggravated if the ascent be made in stormy weather, or when the air is saturated with moisture. The causes of mountain sickness have been variously attributed to diminished barometric pressure, deprivation of oxygen, heart failure, or undue fatigue. A combination of these causes may operate at times, but most authorities are now agreed that the chief of these causes is deprivation of oxygen.

Mountain sickness is associated with an insufficiency in the number of red blood corpuscles which are necessary at higher altitudes to convey oxygen to the tissues. When the ascent is slow and gradual there is a rapid manufacture of the corpuscles. Thus under the stimulus of rarefied air the blood-forming mechanism of the human body brings about a wonderful adjustment to the changed environment.

The most serious effects of a long stay in very high altitudes are felt by the nervous system, which correspond with the acute effects observed in airmen.

Increased pressure of the atmosphere produces effects very much of an opposite nature to those just considered. It is found, however, that the system quickly accustoms itself to increased atmospheric pressure, and that men can work vigorously in diving bells, and in the very deepest mines.

In the compressed air chambers necessary to lay the foundations of bridges and aqueducts under water, the painful effects of exposure to very high atmospheric pressures are generally referred to as "caisson disease." A caisson is a cylinder of iron plates riveted together, which is sunk on the bed of a river so as to form a shaft. Into this, when closed at the top, air is pumped under sufficient pressure to force the water out

of the lower part of the shaft, and to keep it out while men excavate the bed of the river, for the purpose of obtaining a suitable foundation for the piers of bridges. There is at the top part of the cylinder, near to the closing diaphragm, a chamber or "air lock," in which the pressure of the air can be gradually increased or diminished. By this means the men, before entering the compressed air in the shaft, are subjected to a pressure which equals that within the shaft. On leaving the shaft the men are gradually "decompressed" in this lock before emerging into the outside air.

The workers are liable to suffer from the altered conditions of atmospheric pressure to which they are daily subjected, and they are affected far more by the consequences of decompression and returning to the outside air, than from compression and continuance of exposure to the high pressure in the caisson.

The leading symptoms of caisson disease are: (1) Unpleasant sensations or severe pains in the ears, doubtless the result of the tympanum being driven in by the compressed air. The drum of the ear is said to have been even ruptured, and sometimes deafness results. These ear symptoms are materially aggravated if the person happens to be suffering from a cold in the head or sore throat, when pain in the forehead is often marked. (2) Neuro-muscular pains. (3) A feeling of giddiness, with a tendency to fall. (4) Loss of power in the legs, amounting at times to paralysis. (5) Slight to severe pains in legs, arms, and shoulders. (6) Epistaxis. (7) Itching of skin. (8) Hæmoptysis. (9) Epigastric pain, and sometimes nausea and vomiting. (10) Occasionally unconsciousness. There is, of course, a physiological rise in the blood pressure.

Three theories have been adduced to explain compressed air illness. It has been held to be due to CO_2 poisoning; to the mechanical congestion of internal organs; and to increased solution by the blood of the nitrogen in the compressed air, and the liberation of this gas (probably forming gas emboli) during decompression. The last theory is most generally accepted. If the first were correct, the illness should occur while the men are in the caisson, and not after they emerge from it. In support of the second theory, it may be said that in several necropsies the membranes of the brain, etc., have been found deeply congested.

The symptoms mostly yield to recompression, followed by slow decompression lasting some forty-five minutes.

The favouring causes are: Too long stay in the compressed air; insufficient ventilation of the compressed air space—the amount of illness varies inversely with the extent of the provision for ventilation (Snell); too rapid decompression; fulness of habit; advancing age; over-indulgence in alcohol; and organic disease. New hands suffer more than the old.

The preventive measures to be adopted include: Working during short shifts—if the pressure exceeds 35 pounds, the shifts should probably not exceed four hours, and if the pressure reaches 50 pounds, two hours; an abundant supply of fresh air; electric lighting to be employed, so as to insure the continued purity of the air; the rate of decompression certainly not to exceed one minute to every 5 pounds of pressure; the systematic examination of all hands, and the selection of those who are physically sound; advice to be given as to how to inflate the middle ear by swallowing air when uneasiness first appears; as to the importance of rest for a short period after leaving the compressed air; and as to the necessity for extreme temperance with alcohol. It is desirable to temporarily exclude those with a cold in the head or sore throat.

The climate of small islands and of places on the seashore differs from that of the interior of continents chiefly in its greater equability. The variations in temperature between day and night and between summer and winter are much less marked, whilst the winds blowing in from the sea bring a moist but pure air, and free from dust and germs. The specific heat of water is far greater than that of land; hence water heats slowly, and parts with its heat slowly. The land heats quickly and radiates quickly; but on the land it is the surface alone which is affected by the change of seasons. At Greenwich the variations between summer and winter temperatures at a depth of 25 feet are only about 2° F. In winter the ocean acts as a storehouse for the heat absorbed from the summer sun, and slowly parts with it to warm the superincumbent air. In summer the land is heated by the sun more rapidly than the water; consequently, the air over the land is heated and rises, and a cool breeze blows in from the sea during the day. During the night the earth is rapidly cooled by radiation, if the sky is clear; the air over the sea is then warmer than the air over the land, it rises, and a land breeze sets out to

sea. On a summer's day at the seashore the air is constantly in motion, and is cool and moist, whilst in the interior it may be insufferably hot, close and dry. Marshes, by the evaporation from the shallow water, help to lower the summer temperature; but the influence of large lakes, as in North America, is to bring about an almost insular climate in summer, and a continental one in winter, for the frozen lakes then exert a similar influence to land.

Ocean climates are of the greatest benefit to certain cases of lung disease, where a pure air, free from dust, but moist and of equable temperature is desired; but ocean voyages should be recommended with extreme caution to phthisical patients. The confinement and overcrowding in cabins and state rooms, the want of exercise, and the costive habit thus produced (tending to excite hæmoptysis), are all grave disadvantages, and may counteract any benefit to be derived from the sea air.

The effect of vegetation on climate must not be lost sight of. In cold climates trees and shrubs obstruct the passage of the sun's rays to the soil, which is therefore liable to be cold and moist; on the other hand, they may protect against cold winds. In hot climates the evaporation of water from the leaves tends to dry the soil and to lower the temperature, and the ground is sheltered from the direct rays of the sun and kept cool. Thus, the heat of summer is lowered and the cold of winter tempered by the presence of trees, and, having a lower temperature than the neighbouring earth's surface, high forests increase the rainfall. In very dense forests the air is generally stagnant. Probably in all climates a due admixture of herbage, shrubs and trees, without dense undergrowth, but admitting the passage of free currents of air in every direction, is the most conducive to health. Large tracts of country destitute of trees and vegetation are in hot climates unbearably warm and dry, and in cold climates are exposed to every chilling wind. In such districts, too, rainfall is often absent or very slight in amount, the influence exerted by trees upon water-charged clouds being wanting. For these reasons the desert of Sahara gives to the south of Europe a much higher temperature than would otherwise be the case.

The mean temperature of the air of any place is dependent on the latitude, the altitude, the relative proportions of land and water, the aspect, and the nature of the soil; and the extent of the diurnal variations in temperature is largely determined by the proximity of the coast and the height above sea level. The

"amplitude of the yearly fluctuations" in temperature is not more than about 4° F. in some tropical places at sea level, while it may be as much as 110° F., or even more, in the heart of large continents situated near the poles.

The principal factors, therefore, which determine the climate of a district are: (1) Distance from the equator; (2) distance from the sea; (3) altitude; and (4) prevailing winds.

Of the many separate elements that go to make up the climate of a place, temperature is the most important, and the mean annual temperature depends primarily upon the amount of radiant heat received from the sun. The heat received from the sun, however, in one place may be carried by winds and ocean currents to another. The mean temperature of the tropics is about 80° F., and that of the arctic circle in latitude 60° is 25° F., the difference of some 55° F. being due to the fact that the heat received from the sun is concentrated upon a small surface when the sun's rays fall near the equator, and is spread over a large surface when they fall near the poles. The difference would be far greater were it not for the heat carried away from the tropics to the temperate and arctic regions by ocean currents, and to a less extent by winds.

The difference between summer and winter temperatures is also important, but little variation being shown in places within the tropics, or on islands in the middle of large oceans, either in tropical or temperate latitudes.

The heating of the air in the tropics, the cooling around the poles, and the deflective action of the earth's rotation, produce all the prevailing winds of the globe. The colder air of the northern and southern regions of the globe is constantly flowing towards the warmer and more rarefied air over the open seas on both sides of the equator. The result of the earth's rotation on the flow of the warm water from the equator towards the poles in the North Atlantic Ocean is the large circular swirl, the northern and eastern sides of which produce the well-known current of the Gulf Stream. This current, together with the circumstance that the prevailing winds have a westerly direction, accounts for the British Isles possessing such a mild climate; whilst countries with the same latitude as England—such as Labrador and Eastern Asia, in which the prevailing winds are from the land instead of from the sea—have a mean winter temperature below zero.

Weather Observations.

Under the modern system, a number of barometrical readings taken at the same time over an extended area, such as the greater part of Western Europe, are telegraphed to a central station, where they are laid down upon a map. On this map lines are drawn connecting the places showing equal barometrical pressure; these lines are termed "isobars." This weather map will show the cyclonic or anticyclonic systems, as the case may be, their position, and their extent. A cyclonic system is a system having at its centre the lowest barometrical pressure, and surrounded by isobars of gradually increasing pressure. The isobars will be near or far apart according to the amount of depression in the centre. If this depression is great, then the isobars are generally close together, and the "gradients" are said to be "steep." If, on the other hand, the depression in the centre is shallow, the isobars are further apart, and the gradients are "shallow."

An anticyclonic system is the reverse of this, for its centre is the highest barometrical reading, and it is surrounded by isobars of gradually decreasing pressure.

In order to restore atmospheric equilibrium, the air tends to move from a region where the barometer is high and pressure greatest, towards one where it is low and the pressure is least. Consequently, currents of air set in from all sides towards the centre of a cyclonic system, and flow out in all directions from the centre of an anticyclonic system. These currents of air do not, however, as a matter of fact, flow straight to or from the centre, but have a gyratory movement imparted to them owing to the rotation of the earth on its own axis.

The equatorial circumference of the earth being 24,900 miles, and the earth rotating on its axis once in twenty-four hours, it follows that a point on the earth's crust at the equator must be carried round at the rate of 1,040 miles an hour. In latitude 30°, however, the point would only move at the rate of 900 miles an hour, owing to the lesser circumference of the earth at this distance from the equator. In latitude 60° the rate will be only 520 miles an hour, and at the poles it will be nil. Now, the atmosphere is carried round, from west to east, at the same rate as the earth's crust; consequently winds or currents of air travelling from the equator towards the poles tend to keep the

higher rate of rotary motion imparted to them when nearer the equator, and become westerly. In the same way, winds travelling from high latitudes to low ones meet an atmosphere which is rotating at a greater rate than they are, and consequently *appear*[1] to come from an easterly direction. This is the reason why the trade winds which blow towards the equator appear as north-east winds in the northern hemisphere, and south-east winds in the southern hemisphere. This direction of the trade winds is constant over all open seas to about 30° north and south of the equator, but land changes their course. The

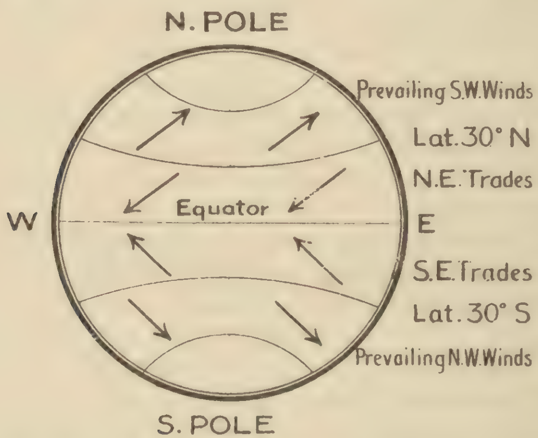


FIG. 37.—DIAGRAM TO ILLUSTRATE PREVAILING WINDS.
The great belts of high pressure are seen to be at latitudes 30° N. and S.

position of the sun has an influence on the strength and direction of these trade winds; when the sun is near the Tropic of Cancer the south-east wind is more southerly and strong, and the north-east wind is weaker and more easterly; and the reverse happens when the sun approaches the Tropic of Capricorn.

The same forces apply to the currents of air moving towards the centre of a cyclonic system, or away from the centre of an anticyclonic system. In the case of a cyclonic system (in the northern hemisphere), a current setting towards its centre from the north appears to come from north-east. A current setting towards the centre from the south of the system is deflected to

[1] As when a steamship is rapidly passing through the air from west to east a wind coming from the north *appears* to come from the north-east.

the east, or comes from south-west. In this way a gyratory or spiral movement is imparted, which causes the wind to travel round the centre of a cyclonic depression, in a direction *against* the hands of a watch; or supposing a person to be travelling with his face towards the direction the wind is taking, he will always keep the centre of the system, *i.e.*, the point of lowest pressure, on his left hand side.

The central space of the cyclone is occupied by a vast ascending current, which after rising to a considerable height flows away as upper currents into surrounding regions.

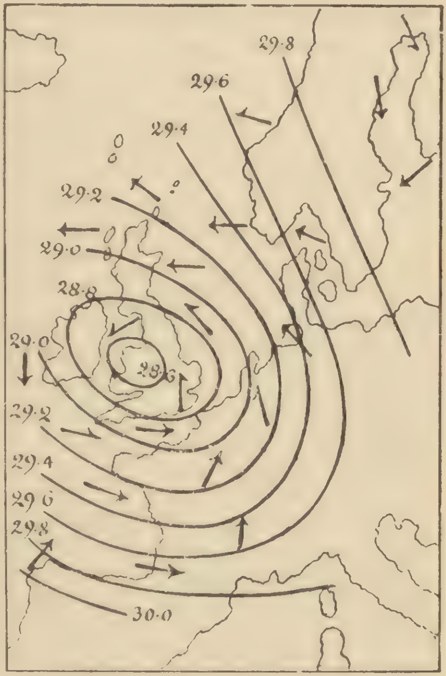


FIG. 38.—SYNOPTIC CHART SHOWING CYCLONIC SYSTEM.

The arrows show the direction of the wind. The figures show the barometric pressure of the isobars.

The direction of the wind round an anti-cyclonic centre is exactly the reverse. The air flows away from the centre of greatest pressure in all directions. The current flowing southwards is deflected to the west, and appears to come from north-east. The current flowing northward is deflected to the east, and comes from south-west. Consequently the currents revolve *with* the hands of a watch, and the person travelling with the wind keeps the centre of the system—the point of highest pressure—always on the right hand.

From this it follows that having a weather (synoptic) chart before us, and knowing the distribution of pressure over the area included in the chart, we can generally tell the direction of the wind at any particular spot; and if we know what course the system is taking, *i.e.*, the direction in which it is travelling,

we can predict what changes will subsequently take place in that direction, so long as it remains included in the system.

Cyclonic systems are never stationary. They move over the earth's surface, usually from west to east in European latitudes; but in the case of the British Isles, coming from off the Atlantic, their approach is difficult to forecast. In these depressions the isobars lie close together and the winds are strong. The greater the depression in the centre and the steeper the gradient, the more violent is the wind; but, according to Scott, no simple relation between the force of the wind and the steepness of the gradient has yet been determined. In this country the arrival of cyclonic systems off our coasts heralds the approach of cloudy skies, wind, rain, and damp air. These conditions imply warmth in winter, and cold weather in summer. The centre of the cyclonic depression usually lies to the north of the British Isles; consequently, these islands lying in the track of the southern portion of the system, the wind is first experienced from the south-east, it then shifts through south to south-west, and blows harder the more rapidly the mercury drops. When the barometer has reached its lowest point the wind flies round to west or west-north-west; the barometer then begins to rise, the rain ceases, the temperature falls, and as the wind becomes north the sky clears, and fine weather is again experienced (Scott).

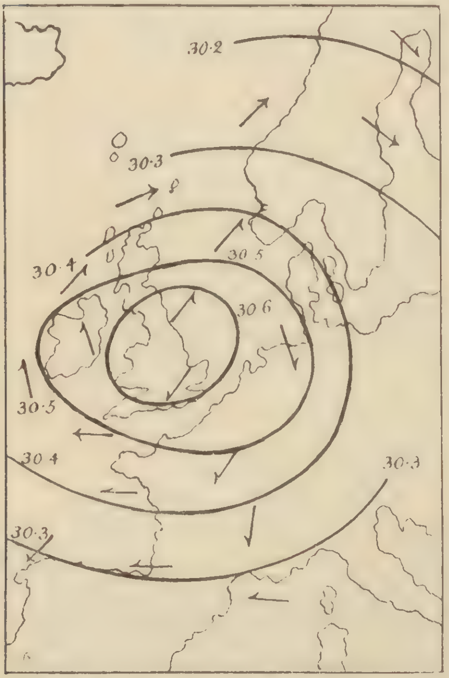


FIG. 39.—SYNOPTIC CHART SHOWING ANTICYCLONIC SYSTEM.

Anticyclones, on the contrary, are generally more or less stationary, or move very slowly. The isobars lie far apart, and

the winds are light. They are accompanied by fine weather, a dry atmosphere, a sky generally clear of clouds, though fogs are very likely to prevail at places. These conditions produce cold, frost, or fog in winter, and heat in summer.

The synoptic charts (figs. 38, 39) show that the wind in both cyclonic and anticyclonic systems has a direction more or less parallel to the isobars, but still, on the whole, tending to cross the isobars very obliquely, so as to blow spirally towards the centre of the cyclone, and spirally away from the centre of the anticyclone.

A *col* is a neck of relatively low pressure connecting two anticyclones. It is comparable to the col which forms a pass between two adjacent mountain peaks.

Meteorological Instruments.

The Barometer.—The pressure of the atmosphere is expressed by means of a barometer in terms of the perpendicular height of a column of mercury, glycerine, or water, which it is capable of supporting. The weight of the atmosphere at the sea level supports a column of mercury of 29·992 inches, or 760 millimetres, in height, a column of glycerine about 324 inches, and one of water 34 feet, in height. The water barometer is accordingly the most sensitive, but it is inconvenient in use.

The simplest form of mercurial barometer is a graduated U-tube, with one end closed. The closed arm is about 32 inches in height, and the open arm about 8 or 9 inches. The mercury placed in the U-tube is made to completely occupy the closed arm, so that all the air is displaced from it; then, when the tube is brought to its proper upright position, and the mercury falls, there is a complete vacuum left above it in the closed arm. The varying pressure of the atmosphere on the surface of the mercury exposed in the open (short) arm causes the level of the mercury to rise and fall in the long (closed) arm; and the difference between the levels in the two arms represents the height of the column of mercury supported by the atmosphere.

In a standard mercurial barometer, a vertical tube 33 inches long rises from a cistern of mercury, the tube above the level of the mercury being in a state of perfect vacuum. In Fortin's standard instrument (fig. 40) the small cistern has a leathern bottom, which by means of a thumb-screw (*a*) can be tightened or relaxed so as to raise or lower the level of the mercury in the cistern. The scale for reading the height of the column of mercury is divided into inches, tenths, and half-tenths ($\frac{1}{20}$) of inches; and to obtain more accurate readings than the scale alone allows, a sliding scale or vernier (*b*) is attached, which serves to indicate the amount of space occupied by the mercury between the half-tenth lines. The vernier scale is divided into twenty-five equal parts, which correspond to twenty-four half-tenth divisions on the barometer scale. Consequently each

division on the vernier is $\frac{1}{25}$ less than a half-tenth division on the barometer scale, and is therefore $\frac{1}{25}$ of $\frac{1}{20}$ inch ($=\frac{1}{500}$ or 0·002 inch).

In order to take an accurate observation, the eye, the zero edge of the vernier, and the top of the mercury, should all be in the same horizontal plane; hence the necessity of fixing the barometer at a height convenient to the observer. The temperature of the attached thermometer (*c*) is first noted; then the level of the mercury in the cistern is so adjusted that the ivory point (*d*) projecting downward from the roof of the cistern just touches the surface of the mercury. This little ivory point indicates the zero of the scale; and since the level of the mercurial surface in the cistern varies with every change of atmospheric pressure, the level of the mercury must be adjusted prior to each observation to the zero of the scale. Next read off on the barometer scale the division immediately below the top of the column of mercury. Then adjust the vernier (fig. 41) so that its lowest line is level with the top of the column of mercury, and the light is just excluded between the lower end of the vernier and the top of the mercury, and count the number of divisions on the vernier from below upwards, until a line on the vernier is exactly continuous with one on the barometer scale. Multiply the number of divisions on the vernier so obtained by 0·002, and add the result to the already observed height on the barometer scale.[1] Corrections, by Glaisher's tables, must then be made for temperature above 32° F.—for mercury, like all other metals, expands with a rise of temperature. The mercury falls about $\frac{1}{1000}$ inch for every foot ascent above sea level, and allowance must be made for this if the observation is made at an altitude.

The barometer must always be carefully and truly fixed by means of a plumb line, in a good light and protected from sunshine, rain, and winds. Before fixing, it should always be ascertained if the vacuum above the mercury is true. To do this, unscrew the bottom of the cistern until the mercury is 2 or 3 inches from the top, and then rather suddenly decline the instrument. If the vacuum is true, the mercury strikes against the top of the tube with a sharp click, but a dull sound results if air is present. In the latter case, screw up the bottom tightly, turn the instrument upside down, and tap the side forcibly until a bubble of air is seen to pass through the mercury column into the cistern. Barometric observations are always expressed to the third place of decimals; and isobarometric lines, as shown on charts, indicate areas over which the barometric pressures are identical. If the isobars, which are drawn for each $\frac{1}{10}$ inch, are close together, the "barometric gradient" is said to be steep, and the wind velocity will be high.

The *aneroid barometer* is a small watch-shaped metal box from which the air has been exhausted, and in which the two flat surfaces of the box are kept apart by a powerful but sensitive spring. The

[1] For instance, in fig. 41 the mercury is shown to reach to a little above 29·55 inches on the barometric scale; taking the seventh line on the vernier as the line which is exactly continuous with one of the barometric scale, then $7 \times {\cdot}002 = {\cdot}014$; and the barometric reading as $29{\cdot}55 + {\cdot}014 = 29{\cdot}564$ inches of mercury.

atmospheric pressure acts upon the spring, and is recorded on a dial. This instrument is chiefly used for taking altitudes. The practice is

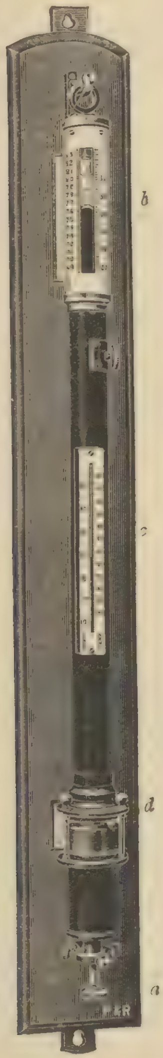


FIG. 40.—FORTIN'S STANDARD BAROMETER.

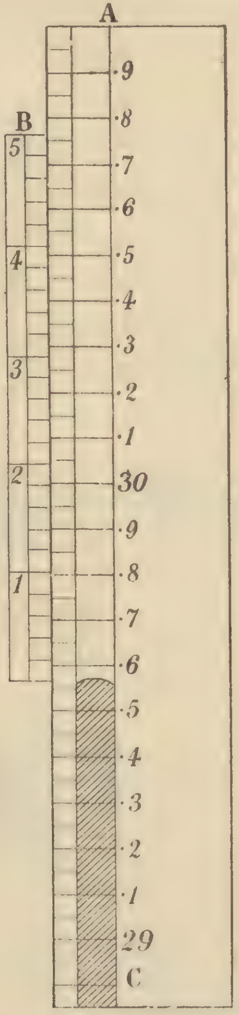


FIG. 41.—DIAGRAM OF BAROMETER SCALE AND VERNIER.
A, scale; *B*, vernier.

to read the aneroid to the nearest $\frac{1}{100}$ inch both at the commencement and at the termination of an ascent, and then to subtract one reading

from the other (ignoring decimal points), and multiply the difference by 9, this giving the height of the ascent in feet.

Example.—

Reading at start=30·00 inches.
Reading at end=29·00 ,,

100
9
900 feet ascended.

The weight of a cubic foot of dry air at 32° F. and 30 inches of mercury is 566·85 grains. As air expands $\frac{1}{491}$ of its volume for every degree rise Fahrenheit, the volume at 60° F., for instance, is $1+\frac{1}{491}\times(60-32)=1{\cdot}057$ cubic feet. The weight is inversely as volume; consequently the weight of a cubic foot of dry air at 60° F. $=\frac{566{\cdot}85}{1{\cdot}057}=536{\cdot}28$ grains.

The weight of a cubic foot of water vapour at 60° F. is 5·77 grains. Therefore, the added weights of a cubic foot of dry air at 60° and of a cubic foot of vapour at 60° are 536·28 + 5·77 = 542·05 grains. But dry air expands on taking up moisture, and the actual weight of a cubic foot of saturated air at 60° is 532·84 grains, or 3·44 grains less than the weight of an equal volume of dry air at that temperature, because the cubic foot of originally dry air is now more than a cubic foot. This fact explains the fall of the barometer when the moisture in the air is increasing and a fall of rain is imminent.

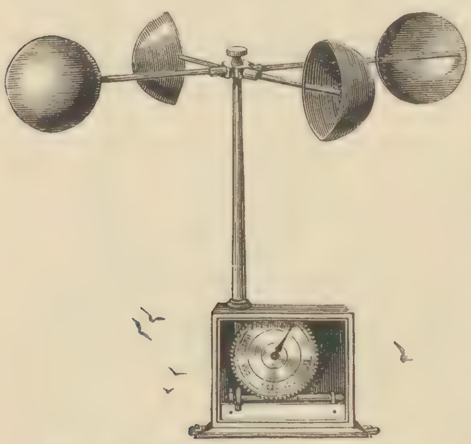


FIG. 42.—ROBINSON'S ANEMOMETER.

Robinson's Wind Anemometer is an instrument which records the velocity of the wind. The figure (42) sufficiently explains the construction of the instrument. The revolving cups set in action a train of clockwork, and the velocity of the wind is recorded on a series of dials. The cups travel at a rate equal to only one-third that of the wind, and allowance is made for this fact in graduating the instru-

ment. The square of the velocity in miles per hour, multiplied by 0·005, gives the wind pressure in pounds per square foot; and on the other hand, the square root of 200 times the wind's pressure gives the velocity.

The instrument must be kept clean and well oiled, and should be fixed at least 20 feet from the ground, and away from buildings. The average velocity of the wind is from six to eight miles per hour.

On the Beaufort scale, in a "light wind," the air travels at a rate of 13 miles per hour; in a "moderate breeze," 23; in a "strong breeze," 34; and in a "gale," 65.

All wind direction observations by vanes, etc., should be recorded to the nearest point of the compass.

The instruments which register the moisture in the atmosphere are known as *hygrometers*. Of these there are two distinct classes, *i.e.*, those which indicate the dew point directly, and those from which the dew point is indirectly determined.

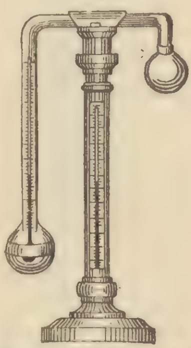


FIG. 43.—DANIELL'S HYGROMETER.

In the former class the air is cooled until the moisture is deposited on a bright surface to which a thermometer is attached, the latter indicating the temperature of the dew point.

In Daniell's hygrometer (fig. 43) ether is placed in the lower bulb, and the other bulb (which contains nothing but ether vapour) is covered with muslin moistened with ether. This ether on the muslin evaporates into the air, and the loss of heat so occasioned condenses the ether vapour inside the bulb, causing evaporation from the ether inside the other (lower bulb). The lower bulb thus becomes gradually colder, and chills the air surrounding it, until a temperature is reached at which the air is compelled to part with some of its moisture, which condenses upon the bright metal band surrounding the bulb. Directly this takes place the temperature of the dew point is read off from the attached thermometer. The temperature at which the dew disappears is next observed, and the mean between these two temperatures is taken as the dew point. In Regnault's instrument (fig. 44) one cylinder is half filled with ether and the other is left empty, thermometers being inserted in both cylinders. An aspirator communicates, by means of the hollow upright, with both cylinders, and when this is put in action air is drawn through them. The passage of the air through the evaporating ether soon cools it down to the dew point, and then the bright metal surface surrounding the lower part of the cylinder becomes dulled with moisture. The temperature recorded at that instant by the thermometer in the ether is the temperature of the dew point, the second thermometer simply showing the temperature of the air at the time of observation. In Dines' instrument a vessel which holds ice-water has a bright

metal plate with an attached thermometer in its roof. As the cold water is made to flow under the plate, the outside air in contact with it becomes chilled; and when the dew point, as shown by the deposition of dew, is reached, it can be read off from the attached thermometer.

Wet and Dry Bulb Hygrometer.—This instrument consists of two absolutely identical thermometers mounted on a stand. In the wet bulb thermometer the bulb is kept moist by being covered with muslin, one end of which dips into a small vessel of distilled or rain water, so that moisture ascends by capillary attraction. The evaporation of moisture from the wet bulb, which takes place so long as the surrounding air is not saturated, causes loss of heat, and the wet bulb reads lower than the dry bulb. Both the vessel containing water and the

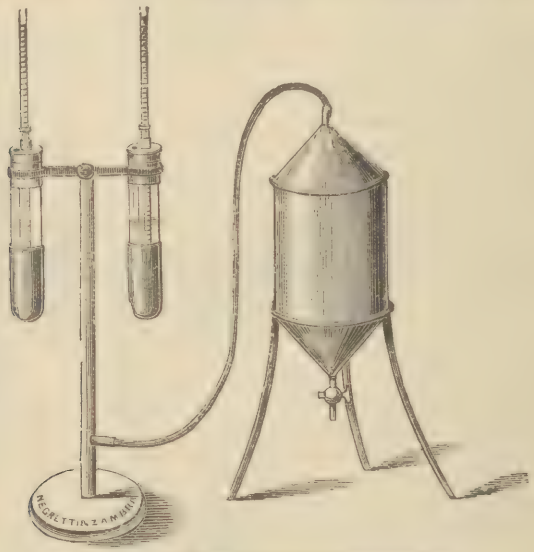


FIG. 44.—REGNAULT'S HYGROMETER.

wet bulb must be sufficiently far from the dry bulb to insure that the readings of the latter are not affected by the evaporation. The instrument must be exposed in the shade and protected from air currents and direct sunshine, both of which, by increasing evaporation, would cause the wet bulb thermometer to indicate a temperature not strictly due to the hygrometric state of the atmosphere. If the muslin becomes frozen in the winter, the two thermometers will read the same; then the wet bulbs should be brushed over with cold water, and the evaporation which will go on from the frozen surface will enable a proper reading to be taken.

From the readings of the dry and wet bulbs can be ascertained the *relative humidity* of the air—*i.e.*, the amount of moisture present in the air, expressed as a percentage of the amount just

necessary to cause saturation; the *dew point, i.e.*, the temperature at which the amount of moisture actually present in the air causes saturation; and the *weight of vapour in a cubic foot of air*, from which can be deduced the additional weight of vapour necessary to cause saturation, or the *drying power of the air*.

The relative humidity is found from tables. The greater the difference between the dry and wet bulbs, the lower is the relative humidity. If the dry and wet bulbs record the same temperature, the air is completely saturated with moisture.

The dew point can be determined by the equation: Dew point $= T^d - F\,(T_d - T_w)$; where T_d is the dry bulb temperature, T_w is the wet bulb temperature, and F the factor opposite the dry bulb temperature found in Glaisher's tables.

In De Saussure's instrument (*the hair hygrometer*), a hair freed from fat by ether is fixed at one end, and this hair contracts with lesser and expands with higher degrees of humidity. The hair is kept stretched by a small weight, the connecting cord of which is led round a pulley; and an index needle attached to the pulley indicates the relative humidity on an empirically graduated scale of relative humidities. The instrument is standardized by first wetting the hair and noting whether it accurately registers saturation on the scale (*i.e.*, 100); but it is necessary to frequently verify the readings by other methods.

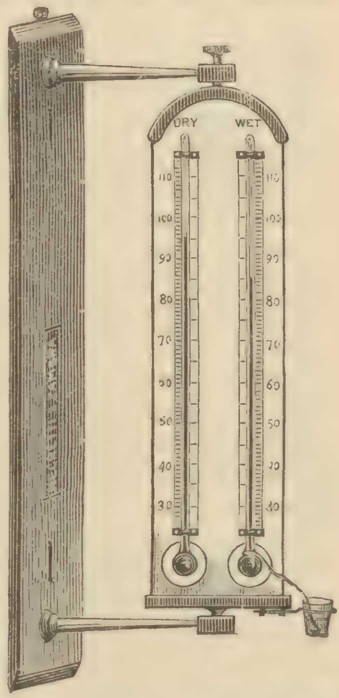


FIG. 45.—WET AND DRY BULB HYGROMETER.

The "elastic force of the vapour," or "the tension of aqueous vapour," is the amount of the barometric pressure which is due to the aqueous vapour in the atmosphere. If the temperature of the air is lowered, and with it the tension of aqueous vapour, a temperature will sooner or later be reached at which the air is saturated with moisture; and then the slightest further reduction in temperature will cause a deposition of dew ("dew point").

The tension of aqueous vapour is ascertained from tables or by formula. The relative humidity can be calculated by dividing the elastic force of aqueous vapour at the temperature of the dew point by the elastic force of the aqueous vapour at the temperature of the air, and then multiplying by 100.

Example.—The dry bulb temperature is 62° F., and that of the wet bulb is 56° F. The dew point is therefore

$$62 - \{ (62 - 56) \times 1{\cdot}86 \} = 50{\cdot}84° \text{ F.}$$

The aqueous tension at 62° F. is (from Glaisher's tables) 0·556 of an inch of mercury, and that at 50·84° F. is 0·372 of an inch. The relative humidity is, therefore, $\frac{0{\cdot}372}{0{\cdot}556} \times 100 = 66{\cdot}9$ per cent. of saturation.

If the relative humidity at 61° F. is 70, the amount of vapour in a cubic foot is 70 per cent. of the amount of moisture (6 grains) which saturates a cubic foot of air at that temperature, or $\frac{70}{100}$ of $6 = 4{\cdot}2$ grains; and the drying power of a cubic foot of the air is $6 - 4{\cdot}2 = 1{\cdot}8$ grains.

Atmometers, for determining the amount and rate of evaporation, have been devised. In these instruments a known volume and weight of water is exposed in a receptacle, so as to present a known surface area to the atmosphere; and the evaporation in a given time is determined by the loss either in volume or in weight of the original water.

The weight of moisture which a cubic foot of dry air can take up, before it is saturated, varies with the temperature. The higher the temperature, the larger is the amount of vapour which can be held, as shown in the table below.

Hence, when warmer air, already moisture laden, is chilled, the moisture representing the difference between what it originally held and what it is capable of holding at the reduced temperature is deposited in the form of dew or rain.

GRAINS OF VAPOUR TO SATURATE A CUBIC FOOT OF DRY AIR (APPROXIMATE).

30° F. 2 grains	66° F. 7 grains	80° F. 11 grains
41° F. 3 ,,	70° F. 8 ,,	83° F. 12 ,,
49° F. 4 ,,	74° F. 9 ,,	86° F. 13 ,,
56° F. 5 ,,	77° F. 10 ,,	88° F. 14 ,,
61° F. 6 ,,		

Rain Gauge.—This instrument consists of a vessel supporting at its top a circular funnel which collects the rainfall. The

vessel must be sunk in level ground, away from shrubs and buildings, to such a depth that the collecting surface is one foot from the ground. A measuring glass, graduated according to the area of the funnel, so as to indicate the fall of rain as decimals of an inch, is required. The area of the top of the circular funnel (the receiving surface for the rain) is usually 50 square inches. To graduate the measuring glass for a funnel of this area, 50 cubic inches of water are poured into it, and a mark placed at the level the fluid stands at. Then if the rainfall collected on 50 square inches should measure the 50 cubic inches, each square inch of surface has collected one cubic inch of water, and the rainfall is "one inch." But the glass below the mark is divided into 100 equal parts, so that each division indicates a fall of $\frac{1}{100}$ or 0·01 inch of rain. The readings are generally taken daily at 9 a.m.

Fig. 46.—Rain Gauge.

In time of snow, the collected snow should be melted by adding a measured quantity of warm water to it, the extra water derived from the snow being recorded as rain-water. The average depth of the adjacent snow should also be noted.

In Crosley's self-registering rain gauge every $\frac{1}{100}$ inch of rainfall is recorded on a dial. The rainfall collected gradually fills one compartment of a small bucket divided into two compartments, and balanced on a pivot. When one compartment is full, the bucket tips and causes an index to record, and the second compartment then commences to fill.

Aqueous vapour requires free surfaces for its condensation. When air is filtered, no cloud of condensed vapour can be formed. "Wet fogs" result when the particles of suspended matter are relatively few and the condensed moisture excessive, whereas "dry fogs" occur when the smoke and dust are relatively abundant. When the films of moisture are discoloured by the products of coal combustion, a yellow or "pea soup" fog will result.

The death-rate generally increases as a result of town fogs, and the increase is ascribed to the irritating effects of the impurities in the atmosphere upon the lungs, and to the sudden fall of temperature which takes place on the occurrence of the fog. Fogs lead to a considerable loss of that important element, sunshine, in our great towns; for, as a rule, when the town is enveloped in fog there is a cloudless sky above.

Clouds consist of collections of condensed aqueous vapour. The principal forms which they assume are: (1) The cirrus, consisting of separate fine feathery formations, generally white in colour; (2) the stratus, consisting of a smooth horizontal stratum of cloud; (3) the nimbus, constituting the raining clouds, of dark-coloured, irregular forms; and (4) the cumulus, or heavy, thick, well-defined clouds, generally rounded off in shape. Two or more of these four principal forms may be mixed together, giving rise to appearances which are defined as "cirro-stratus," "cirro-cumulus," "strato-cumulus," "cumulo-nimbus," etc.

Thermometers measure the temperature from the amounts of expansion and contraction of certain bodies when these are exposed to varying degrees of heat and cold. Mercury is commonly employed, because of its very low freezing point ($-38°$ F.) and its high boiling point (675° F.); but alcohol is preferred when very low temperatures may have to be recorded, because it does not freeze at the greatest known degree of cold.

The instruments are graduated from the fixed points of freezing and boiling water, by plunging them into melting ice and boiling water, respectively, at the standard pressure. On the Centigrade scale the freezing and boiling points are 0° and 100° respectively, while on the Fahrenheit scale the freezing point is 32° and the boiling point 212°; therefore, to convert Centigrade to Fahrenheit, multiply the former figure by $\frac{9}{5}$ and add 32, while to convert the Fahrenheit to Centigrade subtract 32 and then multiply by $\frac{5}{9}$.

Maximum thermometers are instruments designed to register the highest temperature reached during the period of exposure of the instrument; in these the temperature is registered by mercury. The registration is effected by either breaking the column of mercury by an air bubble, or by a slight narrowing of the tube near the bulb. In either case the natural cohesion of the metal when contracting is overcome, and the mercury always remains at the highest point reached. Another method is to insert a small piece of solid glass enamel in the bend near the bulb; this, acting as a valve, allows the

mercury to pass on one side of it as it expands, but does not allow it to return on cooling. In hanging a maximum thermometer, it is necessary to see that the end of the tube furthest from the bulb is slightly inclined downwards, to assist in preventing the return of any portion of the column of mercury into the bulb on a decrease of temperature. Before reading the instrument, the end furthest from the bulb should be gently elevated to an angle of about 45°.

Minimum thermometers record the lowest temperature reached. They are alcohol instruments, with an index in the alcohol (Rutherford's) which moves with the spirit on contraction by cold, owing to capillary attraction, but not on expansion, and is therefore left registering the lowest temperature. The end of the index furthest from the bulb indicates the minimum temperature. Occasionally air bubbles appear in the alcohol and fix the index. They can be removed by holding the thermometer with the bulb downwards, and swinging it round rapidly at arm's length. These instruments should be hung so that the bulb end is 1 inch lower than the other end, because then the index is less likely to be affected by a rise in temperature.

The so-called "*earth*" *thermometer* is a maximum thermometer which is suspended by a chain in a stout iron tube, 5 feet long, which is provided with a pointed metal cap. By this means the temperature of the earth at depths up to nearly 5 feet can be ascertained. In taking an observation the thermometer must be quickly drawn up and read.

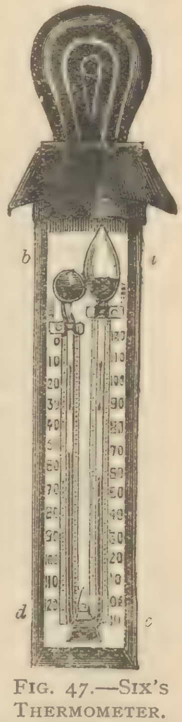


FIG. 47.—SIX'S THERMOMETER.

In *Six's thermometer* (fig. 47) there is a U-tube, the middle part of which is occupied by mercury. The bulb (*a*) and both tubes above the mercury contain alcohol, in which are two steel indices, which are brought by means of a magnet to rest upon either column of mercury; and (*b*) is a small chamber containing air. On a rise of temperature, the alcohol, expanding in the bulb (*a*), depresses the mercury level in one arm, and therefore raises it in the other, the maximum temperature being indicated by the position reached by the lower end of the index. Conversely, as the temperature falls the alcohol in the bulb contracts, and the pressure of the air in the chamber (*b*) depresses the mercury level in the arm immediately beneath, and therefore raises the mercury level in the other arm, in which the index then registers the lowest temperature experienced. Thus, in the arm (*c*) maximum temperatures are registered, and in the arm (*d*) minimum temperatures.

A *barograph* and a *thermograph* are instruments which furnish a record of the barometric pressure and of the temperature for the whole twenty-four hours of the day and night. The records are traced on slowly revolving drums worked by clockwork. The instruments require repeated standardizing. In the recording aneroid barometer the fluctuations of atmospheric pressure act upon

a series of aneroid vacuum chambers, a sensitive index attached to the latter recording the results. In one form of thermograph the record is continuously marked by an index attached to a delicate metal spring, the expansion and contraction of which is dependent on the atmospheric temperature.

Isochimenal lines are lines drawn through districts, as shown on a chart or map, having the same winter temperature; and isothermal lines similarly indicate districts with the same mean annual temperatures.

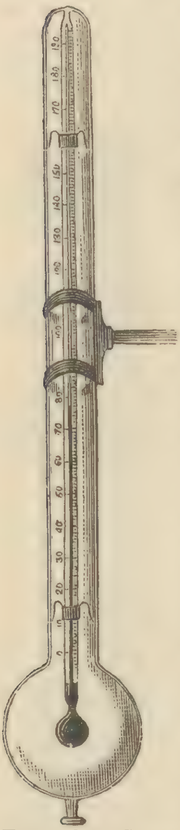


FIG. 48.—SOLAR RADIATION THERMOMETER.

Shade maximum and minimum thermometers should be placed horizontally in the shade, or in a Stevenson's louvred box, 4 feet above the ground and at least 20 feet away from buildings or other sources of radiation.

The *vacuum solar radiation thermometer* (fig. 48) is a mercurial maximum self-registering instrument, with a blackened bulb, which absorbs the sun's rays. It is placed in a glass case from which air is exhausted, thus protecting the bulb from loss of heat, which would ensue if the bulb were exposed, owing to atmospheric currents and the absorption of heat by aqueous and other vapours. This instrument is placed 4 feet above the ground, and is directly exposed to the sun's rays. The bulb should point south-east in this country. The difference between the maxima in the sun and in the shade is a measure of solar radiation, or of the power of the sun's rays.

Other instruments which may be found useful are: A *terrestrial radiation thermometer*, which is merely a minimum shade thermometer placed close to the ground, the bulb resting on grass—the difference between this minimum temperature and the air minimum in the shade being taken as the amount of terrestrial radiation; a *sunshine recorder* (Campbell-Stokes', fig. 49), a little instrument by which the rays of the sun are concentrated on to a strip of millboard stretched in a frame at the proper focal distance from a large spherical lens. When the sun shines, a charred line is burnt in the millboard, and when hidden by clouds the record ceases. Results are best expressed as a percentage of the possible sunshine; *i.e.*, if the sun is above the horizon ten hours, and the record is but one hour, the sunshine equals 10 per cent. of the possible amount.

Jordan's instrument is a sunlight rather than a sunshine recorder. By this instrument a straight line of sunlight is recorded on sensitive cyanotype paper placed in two semicircular dark chambers. The sunlight, being admitted through small apertures in the sides, travels over the sensitive paper or chart by reason of the earth's rotation, and leaves behind a record of the duration of sunlight and the relative degrees of its intensity. The instrument must be carefully adjusted

to the meridian and to the latitude of the place. To this end the base plate of the instrument must be inclined until the index points to the divisions on the arc corresponding to the latitude of the station; then turn the instrument until it faces due south, taking care that the base is perfectly level. When the sun is on the meridian, the sunshine passing through the apertures should fall on the chart line indicating twelve o'clock. One box takes the records for the forenoon, and the other for the afternoon, thus enabling the charts to be changed without interfering with a continuous record.

Atmospheric Electricity.

The atmosphere is charged with electricity, which is chiefly positive in fine weather and negative in wet. The sources of this electricity are: (1) Vegetation, (2) evaporation from waters containing salts in solution, (3) the unequal distribution of heat, leading to atmospheric friction, and (4) combustion at the earth's surface (giving off positive electricity). Vegetation furnishes electricity by the evaporation of moisture, and by the giving off of CO_2 and O charged with positive electricity.

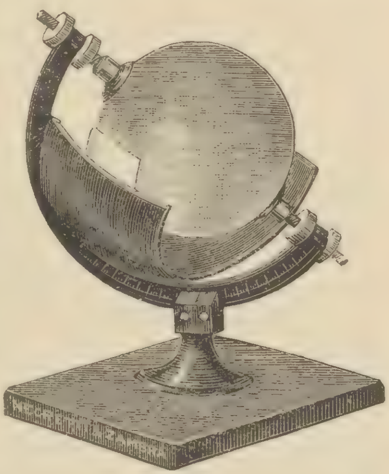


Fig. 49.—Sunshine Recorder.

When clouds charged with different electricities (positive and negative) approach each other, a thunderstorm results. The heat generated along the track of the electric discharge causes the "lightning," and the thunder probably results from the sudden expansion of the air consequent upon the lightning, and the subsequent inrush of air to restore the resulting partial vacuum.

Lightning rods are generally of iron of about 1 inch in diameter, and pointed with copper. They are carefully insulated, one end being buried in the ground. They must be fixed at a distance from any of the metal pipes of a building.

CHAPTER VII

EXERCISE, CLOTHING, AND PERSONAL HYGIENE

EXERCISE.

THE effects of exercise on the body are as follows:—

1. Increased force and frequency of the heart's action, and by consequence the increased circulation of the blood through all parts of the body. 2. The pulmonary circulation being quickened, more carbonic acid and moisture are eliminated. The amount of air inspired and expired is largely increased by quicker and deeper inspirations. These deeper inspirations cause, besides, a more efficient "massage" of the abdominal organs, thereby benefiting the circulation of blood and counteracting venous stasis. 3. The action of the skin is heightened, and perspiration becomes marked. The dilatation of the cutaneous bloodvessels, and the evaporation of the sweat from the surface of the body, regulate the temperature and prevent any rise above the normal. 4. The water and salt of the urine are decreased owing to the large cutaneous secretion, but the nitrogen eliminated (in the form of urea, uric acid, and extractives) remains about the same. In the period of rest following excessive exercise, the nitrogen elimination may be slightly increased. 5. The voluntary muscles are brought into active play; the circulation of the blood through them is accelerated; waste products are rapidly carried away for excretion; whilst the material to replace waste is brought to them.

It is thus seen that exercise, which means muscular action, involves more rapid combustion, as shown by the increased elimination of carbonic acid and water. Thirst and appetite are created, and water and carbonaceous foods are required to supply the waste; whilst an increased amount of nitrogenous food, during or after periods of exercise, is necessary to replace the waste caused by the nitrogenous tissues performing their function of regulating oxidation.

Regular exercise in the open air is most essential to brain workers, to purify the blood from waste matters, and to stimulate the action of the bowels; but exercise of the muscles generally is necessary for the healthy performances of all the functions of the body. Well-developed muscles are requisite for all active spontaneous movements. Over-development of isolated groups of muscles, such as may be produced by too specialized physical exercises or gymnastic feats, should not be sought for, as they do not tend to the harmonious working of all parts of the body, and may actually hamper free movements in unaccustomed directions. The aim should be to encourage general strength and activity, and not to attain special expertness in feats of strength controlled by isolated groups of muscles. The natural exercises, such as walking, running, riding on horseback, fencing, boxing, rowing, and all the various games in which co-ordinated movements of many muscles (hands, fingers, arms, legs, trunk, head, neck, and eyes) are concerned, are superior both for physical, mental, and moral training, to physical exercises carried out to the word of command. Games inculcate courage, control of the temper, self-restraint, and obedience to discipline, combined with the desire to win; but the latter should not be allowed to overrule fairness and good temper to opponents, and the desire to show individual excellence should always be subordinated to the desire to do what is best for one's side.

After active exercise the body should be well washed with soap and water to remove the secretion from the sweat and sebaceous glands, which, if left on to dry, becomes mixed with shed epidermic scales from the scarf-skin, and renders the skin dirty and damp. The damp skin causes surface cooling, and often gives rise to a dangerous internal chill.

If the exercise is too severe the heart is overstrained, breathlessness and palpitation are brought on, and the pulse becomes small, very frequent and irregular. Gymnastic and other muscular exercises, which involve the fixation of the walls of the chest for an undue period (more than a few seconds), and consequent arrest of the respiratory movements, are particularly liable to produce heart strain and subsequent dilatation of the heart. An indication of the possible injurious action that may result is afforded by the occurrence of congestion of the veins and lividity of the face during the muscular effort. In the British Army, since the modified Swedish forms of exercises

have replaced the old-established gymnastic exercises, and the drill with constantly expanded chest has been abandoned, there has been a coincident diminution of cases of disordered action of the heart and valvular heart troubles. The physical training exercises which least interfere with the normal rhythm of respiration, and which do not necessitate any postures implying strain or tension of the chest and abdomen for prolonged periods, are the most suitable, especially for the young of both sexes. Prolonged exertion of a severe kind tends to cause cardiac pain and palpitation, and may give rise to hypertrophy of the left ventricle, if the over-exertion is habitual. Rupture of blood-vessels from over-exertion is uncommon before middle life. Thus hammer-men in iron factories, owing to the excessive strain they are put to, sometimes develop disease of the aorta, ending in aneurism, and also disease of the valves of the heart. In others, degenerative changes gradually appear in the organs of circulation, which ultimately unfit them for strenuous labour, and lead to conditions of permanent ill-health.

The muscles, including the cardiac muscle, require rest to get rid of the accumulated products of their action (possibly lactic acid), and to take in a fresh store of oxygen. Without definite periods of rest suited to the kind of exercise, the muscles become exhausted, and their contractions are gradually enfeebled, until they cease altogether. The diastole of the heart is quite sufficient for its recuperation when the body is at rest.

The diet of men in training should differ little, if at all, from an ordinary diet. The amount of fat and nitrogenous food may be somewhat increased out of the usual proportion to the carbohydrates; but to deprive men of bread, potatoes, and vegetables, and to feed them on half-raw beefsteaks—as was formerly so largely done—is a ready means of causing the "staleness" so well known to trainers. Plenty of water, in small quantities at a time, should be allowed as the system demands. After a few days of training, excessive thirst and excessive sweating disappear, and the right balance between income and outcome of fluid is quickly struck. The capacity of the chest and the elasticity of the lungs and chest walls are notably increased by well-regulated training, especially by training for rowing.

From numerous observations it has been deduced that an ordinary day's physical work for a healthy man is equivalent to 300 tons raised 1 foot (foot tons). This is an amount of work

which can be sustained day after day without loss of weight and without inconvenience. Work represented by over 400 foot tons daily cannot be kept up unless the diet is much increased, and even then there is likely to be loss of weight and muscular vigour. It has been shown that a man walking on a level surface at the rate of three miles per hour does work equivalent to raising his own weight, plus the weight he carries, a height equivalent to one-twentieth the distance walked. At quicker rates of speed this "co-efficient of traction" more nearly approaches unity; thus, at four miles an hour it is between one-sixteenth and one-seventeenth, and at eight miles per hour the co-efficient is barely one-tenth. The following formula is useful for estimating the amount of work done by a man in walking:—

Let W = weight of the man in lbs.,
W' = weight he carries,
D = distance walked in feet,
C = co-efficient of traction.

$$\text{Then } \frac{(W + W') \times D}{2{,}240} \times C = \text{foot tons.}$$

(2,240 is the number of pounds in a ton).

About seventeen miles at three miles an hour, for a man weighing 150 pounds and carrying no weight, will be found to amount to an average day's work of 300 foot tons.

Clothing.

The ordinary garments of civilized life are made either of one, or a mixture of two or more, of the following materials: cotton and linen from the vegetable kingdom; wool and silk from the animal kingdom.

Cotton materials have a smooth, fine texture, but not equal in these respects to linen. Under the microscope cotton is seen to consist of flattened fibres with well-marked twists in their course. There are no joints or nodes, and no branching fibres (fig. 56).

Cotton garments are durable, and do not shrink in washing. They are non-absorbent, and rapidly conduct away heat; hence cotton is the wrong material for undergarments, for it soaks up the perspiration and becomes wet, and the moisture is re-evaporated, causing a chill to the surface of the body. The heat of the body is not retained by cotton, but is rapidly dissipated. A material called "cellular" cotton cloth obviates the last defect.

In this material the fibres are so woven as to form cellular air interspaces in the texture. Air being a bad conductor of heat, the cellular cloth is much warmer than ordinary cotton clothing. Cotton materials are preferable to woollen for the outer clothing

FIG. 50.—COTTON FIBRES (× about 200).

of sick and hospital nurses, as organic matters in the air cling far less easily to cotton than to wool, and the former is more readily cleaned.

"Flannelette" is a highly inflammable cotton material, which, on account of its warmth and cheapness, has been largely used. This material has been responsible for the loss of many lives by

FIG. 51.—LINEN FIBRES (× about 200).

burning, and as a consequence much of it now sold is first rendered non-inflammable; but after many washings the previously treated flannelette returns to its highly inflammable condition.

Linen materials have a very fine, smooth, and close texture. Under the microscope the fibres of linen are seen to be cylindrical

and jointed, with minute branching filaments at intervals (fig. 51). These latter are the elementary fibres of which the main fibre is composed. Linen is, like cotton, a good conductor of heat and a bad absorbent and retainer of moisture, and is an unsuitable material for underclothing.

Wool forms a valuable material for clothing. Under the microscope the fibres (fig. 52) are seen to be rounded, colourless (unless dyed), with fine cross-markings and indentations in the border at the site of the cross-markings. There is a central longitudinal canal, but it is generally obliterated. The cross-markings and reticulations are best seen in new wool, as when the fibres are old and worn they are not so distinct.

Wool is an extremely bad conductor of heat, and is very absorbent and retentive of water and moisture, hence its value as a material for underclothing. Being a non-conductor, wool is warm by preventing the dissipation of the bodily heat. Its non-conducting properties are partly due to the wool fibres themselves, which contain an animal oil in their substance, and partly to the air entangled in their interspaces. After exercise causing perspiration, the moisture is absorbed and retained by the wool, and the vapour is condensed, thus giving back to the body the heat rendered latent by evaporation from the surface of the skin. A woollen garment after exercise is therefore warm and dry, and prevents the chilling of the surface from the lowering of the temperature by evaporation, which is so dangerous. In hot climates especially, wool should be worn next the skin to ward off those chills which are often the forerunners of dysentery, diarrhœa, and ague.

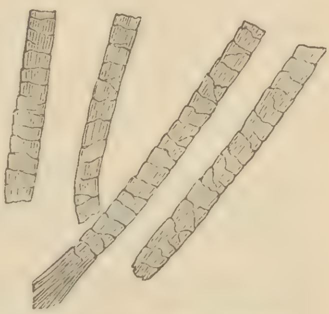


FIG. 52.—WOOL FIBRES ($\times$ about 200).

The disadvantages of wool are the hardening and shrinkage the fibres undergo when frequently washed (especially where soda and strong soaps are used), and the loss of absorbency resulting therefrom. The wool fibres, being hygroscopic, readily absorb organic vapours and dirt from the body, so that woollen under-garments require frequent but careful washing. They should be washed in soft, cold, or tepid water, with mild soap without soda,

and should not be much wrung out. Flannel, which is a woollen material, is also often found to be too irritating to be worn next to a delicate skin.

The addition of a little kerosene or paraffin to the soap used for washing clothes facilitates the removal of dirt, as less rubbing and wringing of the clothes are then required; but the clothes must be well rinsed after the washing and aired out of doors, or a slight odour of kerosene (when kerosene soap is used) is retained in the fabrics. The paraffin soaps are free from this defect. The grease and dirt cannot be removed from clothes (any more than from the skin, owing to the fatty secretion from the sebaceous glands at the roots of the hair follicles) by merely washing in water without the use of soap. The alkali of the soap combines with the grease and emulsifies it, whereby it is easily

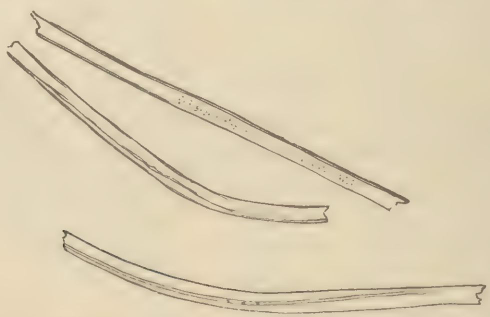


FIG. 53.—SILK FIBRES (× about 200).

washed off; whilst the fatty acid prevents the too great removal of the oil from the wool fibres, and the deterioration of the fabric. Cheap soaps, containing an excess of alkali, are bad for the skin, for it is rendered over-dry and loses suppleness by excessive removal of sebaceous secretion; and they are also injurious to woollen fabrics by carrying away the animal oil contained in the fibres.

In merino, wool and cotton are mixed in varying proportions. "Shoddy" is old, used and worked up, wool and cloth.

Silk (fig. 53) is a bad conductor of heat, but is less absorbent than wool. It presents some advantages for underclothing, as it is more cleanly and shrinks less than wool, and is less irritating to the skin; but it cannot hold perspiration like wool. It is expensive, and is less durable than cotton or merino.

Thus the qualities of hygienic clothing are contained not so

much in the fibre itself as in the manner of weaving and the looseness or tightness of the complete garment. That is to say, the same results can be obtained with wool, cotton, or linen by weaving out of each a material with the same " porosity " and air-holding power, permeability to moving air, and water-evaporating power.

Leather and Waterproof Material.—These are invaluable for exposure to very cold bleak winds and rain. Leather is the more suitable for very cold climates. Being impermeable, they are extremely warm, but this impermeability prevents the ventilation and renewal of the layers of air confined under the clothing near the skin. The discomfort that arises from the wearing of waterproofs in warm weather is well known.

In hot climates the outer garments should be white or grey in colour to protect from the direct rays of the sun, and worn loose.

At the two extremes of life—in childhood and old age—warmth of covering is most essential. Children lose heat rapidly and are liable to chill, partly because the circulation being rapid, more blood is carried in a given time to the superficial vessels, and more heat is thus radiated from the surface than in an adult; but mainly because in children the surface of the body is larger in proportion to its bulk or contents than is the case in adults.

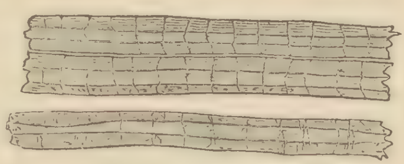


FIG. 54.—HEMP FIBRES (× about 200).

Children should be clothed in woollen materials; and the legs, arms, neck, and chest should be equally protected with the other parts of the body.

In old age the circulation is often feeble and languid, and the functions of heat-production and regulation are less efficiently performed than before senile decay commences. Consequently, if the body is chilled, the restoration to the normal heat is slow, and the vital functions are dangerously depressed.

Aniline dyes are now largely used for colouring various dress materials and undergarments, such as stockings. As a rule the dyes used are free from arsenic; but it has occasionally happened that eczematous sores have been produced on the feet and legs by wearing dyed stockings, and there can be but little doubt

19

that the sores were due to the action of arsenic on the skin when the feet were hot and damp.

A good material for clothing purposes must meet the following requirements:—

1. It must afford proper protection to the body against cold and heat, so as to assist in preserving it at a proper uniform temperature in winter and summer alike.

2. It should interfere as little as possible with the natural functions of the skin.

3. It must exert no irritating or poisonous effects upon the skin.

4. It must not be highly inflammable.

It has been seen that clothing is warm in proportion to its capacity for retaining the natural heat of the body, and, therefore, the materials which are the worst conductors are the warmest. Arranged in the order of their warmth, the materials in common use are: Wool, fur and down, silk, cotton, and linen. But it must be borne in mind that the warmth of an article of clothing also depends upon certain other subsidiary circumstances. Thus the *colour* of the most external clothing is important, black absorbing more of the heat from external sources than any other colour, and white the least of all. The order in which the different colours absorb heat is as follows: black, dark blue, light blue, dark green, turkey red, light green, dark yellow, pale straw, and white. The degree of porosity of the article also affects its warmth, for the small spaces are occupied by air, which is a bad conductor of heat; flannel is the most porous article of clothing, and silk is the least porous. Again, the textile fabrics with rough surfaces are generally warmer than those which are smooth, the rougher surfaces stimulating the skin and favouring the capillary circulation. The hygroscopic properties of the material determine its warmth to a considerable degree, for this property of absorbing moisture enables the fabric to absorb the perspiration from the skin; and the chilling effect of the evaporation of this natural moisture is thereby transferred from the skin to the article covering it. The following is the order in which the various articles of clothing must be placed, so as to indicate their relative hygroscopic properties: wool, fur, eider-down, silk, linen, cotton. The same order will indicate the facility with which each material absorbs odours.

A few general remarks may next be made upon the requirements of suitable and healthy clothing. The clothing of the body

should be designed for the following purposes:—(1) For preserving the whole of the body at a uniform temperature. Doubtless the dress of women and children offends chiefly against this requirement. Women's dress encourages a very unequal distribution of warmth; the upper part of the chest and the legs are unduly exposed, whereas the trunk below the upper part of the chest is, by comparison, clothed very warmly. The dangerous habit of exposing the bare legs and arms of infants to the vicissitudes of our winter climate, and swaddling the rest of their bodies with many layers of warm clothing, should be obvious to all. (2) Clothing must interfere with no natural function or movement, so as to lead to injury of the part of the body to which it is applied.

The head covering should be light, porous (so as to admit air), and with no tight rim to press upon the scalp and interfere with the circulation of its blood supply, which is a cause of baldness. No tight-fitting article should be worn round the neck, as important vessels are specially liable to be pressed upon in that situation. The trunk and extremities have probably suffered most from the adoption of bad principles in clothing; and the dress of women in many respects still defeats the main objects of clothing. Petticoats and dresses are often heavy; they impede movement and accumulate dirt, and they exert a dragging weight from the waist and hips. They should either be, like the male's trousers, suspended by braces, or hung from a bodice by means of buttons.

The effects of tight lacing are to deform the body and to displace important viscera. The diaphragm is pushed up, the lung space diminished, and the lungs and heart often suffer in consequence. Constriction and displacement of the liver are produced, and the resulting pressure on other important abdominal organs causes them to suffer also. Those who lace tightly are frequently, therefore, the victims of dyspepsia, malnutrition, gastralgia, vomiting, shortness of breath, palpitation and faintness. Tight, rigid corsets give rise to muscular flabbiness, which conduces to spinal curvature, round shoulders, and a stooping carriage. The waist of the average woman should be from 26 to 27 inches in circumference.

Tight sleeves should also be avoided. Suspenders should always be preferred to garters; and the lower extremities of women should be protected by thicker stockings in the winter.

The substitution of warm "bloomers" for the petticoat is a practice to be commended.

With reference to boots, these should fit the foot, and at the same time admit of free movement. The natural shape of the human foot is that of a fan—from the heel to the toes. The big toe should be in a straight line with the instep, and not bent outwards towards the other toes. Tight or badly fitting boots may give rise to flat foot, ingrowing toe-nails, corns, bunions, and even to permanent lameness. The soles should be flexible, and the heels kept low. High heels cause the foot to press forward in the boot, tiring the walker and causing a feeling of discomfort. They also give rise to an uncertain and unbecoming gait.

In conclusion, it may be said that clothing should not be changed according to calendar, but according to weather; and that clothing worn in successive layers is warmer than when a similar weight of material is applied in a single layer.

Personal Hygiene.

The Care of the Skin.—The skin by surface radiation and evaporation regulates the temperature of the body. It is also an excretory organ, as it contains in its substance innumerable sweat glands, the ducts of which open on the surface. Sweat or perspiration is a slightly acid fluid, holding in solution nearly 2 per cent. of solid substances, chiefly common salt, and various fatty acids and fats. Besides the sweat glands, the skin contains sebaceous glands, which secrete sebum, a fatty substance, whose function is to keep the skin and hair smooth, moist, and supple. The skin is, therefore, constantly exuding sweat and sebaceous matter, which, mixed with shed epidermic scales or scurf, accumulate on the surface, and must be periodically removed if the surface of the body is to be kept in a clean and wholesome condition. Some of this matter penetrates into the underclothing worn next to the skin, thus rendering periodical changes of underclothing necessary.

A dirty skin and dirty clothes are not only disagreeable to the senses, but are injurious to health, foul and decaying matters on the surface of the body tending to block up the pores, and being liable to absorption into the lymphatic vessels of the skin should there be any chafing or abrasion of the surface, giving rise to

inflammation of the lymphatics and lymphatic glands. Uncleanly people are also more liable to chill than those whose skins are clean. The salt in the dried sweat adhering to the skin tends to absorb moisture from the air, and the damp skin acting as a good conductor of heat, leads to surface chilling and the production of cold.

Lice.—A dirty skin and clothing also form an attraction for lice. There are two kinds of lice commonly infesting the human body—the head louse (*Pediculus capitis*), and the body louse (*Pediculus vestimenti*). The head louse is a small, oblong, ashy-white insect, the female averaging $\frac{1}{8}$ inch in length, and the male about half this size. It infests the hair of the head; and the female lays numerous eggs in small, conical, chitin-covered baskets (nits), which are attached to the shafts of the hair, usually near the skin, by a gluey substance. The embryos in the nits take some 8 to 10 days to incubate, and then appear as grown lice. Lice bite the skin and suck blood, the bites inducing great irritation. This leads to scratching and the formation of unhealthy sores and scabs with painful enlargements of the lymphatic glands in the neck.

The body louse closely resembles the head louse. It lives in the creases of the garments next the skin, and also sucks blood from the skin after biting. The female deposits its ova on the wool or fibres of the garments it infests, and the embryos are hatched out in about a week. Both head and body lice are transferred from person to person by close contact, or by the wearing of lice-infested caps or clothes.

Head lice are best got rid of by cutting the hair very short, or by the application of paraffin to the head with the subsequent use of a fine tooth-comb dipped in 10 per cent. acetic acid solution to comb out the nits; and body lice are destroyed if the garments they infest are well baked or disinfected by steam heat. A useful measure for those who are exposed to contact with verminous persons, such as troops on active service, is to smear the inside surfaces of all the seams of the undergarments with a greasy ointment (ammoniated mercury in soft soap), the effect of which is to asphyxiate the young lice, as they hatch out from the ova, by the occlusion of the respiratory stigmata. A dusting powder containing 2 per cent. iodoform, 2 per cent. creosote, and 96 per cent. naphthalene sprinkled inside the clothing is also effective in keeping lice away.

Baths.—Inasmuch as the dirt to be removed from the surface of the body is largely fatty matter, the application of water merely is insufficient. Hot water, soap, and plenty of friction with the hands or a flannel are necessary to secure perfect cleanliness. Hot water is required to dissolve the fats in the skin secretion, and soap is necessary as an adjuvant. Soap is essentially a compound of an alkali with a fatty acid. The alkali of the soap, when rubbed into the skin, combines with the greasy matters, and enables them to be easily washed off with water; whilst the use of the fatty acid is to prevent the excessive removal of the sebaceous secretion, by which the skin would be rendered over-dry, cracked, and chapped.

Coarse soaps containing an excess of alkali are injurious to the skin, especially in cold weather, as they remove too much of the sebaceous secretion. For young children with delicate, sensitive skins, super-fatted soaps, containing no free alkali whatever, are often desirable. In very cold and also in very hot countries, the native custom of anointing the body with oils is physiologically a sound one. Exposure to the burning rays of the sun, as well as to intense cold, is liable to cause injury to the skin, which the application of oils has considerable effect in preventing.

After a bath the skin should be rubbed quite dry with a rough towel. During this process the loosened epidermic scales are removed, the circulation of the blood through the superficial capillary vessels is increased, and the skin is materially improved in texture and appearance. Whilst the chief use of the hot bath is for purposes of cleanliness, it has also a sedative effect upon the nervous system, tending to allay restlessness and excitability, and to promote refreshing sleep. Hot baths are best taken before retiring to bed, and not on getting up in the morning, as the body is rendered sensitive to changes of temperature and is easily chilled when the cutaneous bloodvessels have been relaxed by heat. After a hot bath or a Turkish bath taken in the day-time, the body should be plunged in cold water for a few seconds to restore tone to the superficial bloodvessels.

Cold baths are less cleansing than hot, but more stimulating and invigorating. The best period of the day for a cold bath is at rising in the morning. The immediate effect is the withdrawal of heat from the body and the lowering of its temperature; but this is followed very shortly by reaction—a feeling of warmth

and glow—due to dilatation of the previously contracted cutaneous bloodvessels, which is accompanied by a feeling of exhilaration and increased energy. After leaving the bath the skin should be rapidly rubbed dry with a rough towel, and warm clothes quickly assumed.

A cold bath which is not followed by reaction is likely to do more harm than good. The absence of reaction may be due to the water being too cold, the bath being too prolonged, or the bather being in a poor condition of health. The temperature of the water should be regulated to the age and strength of the bather, and as soon as reaction is established the bath should cease. To remain in the water until a sensation of cold is experienced is to render bathing not only devoid of benefit, but actually detrimental to health. Outdoor bathing in sea, river, or lake, should not be indulged in until at least two hours have elapsed since the last meal; and except for the robust it is wisest not to bathe on an empty stomach. Cold baths are not well borne by very young children; and for most people it is unwise to continue the daily cold bath in winter after middle age is reached, unless the water is rendered tepid.

Even if the whole body is not washed daily, the feet should never be neglected, as a large amount of perspiration is given off by the sweat glands on the soles of the feet even in the coldest weather. This should be daily removed by washing, together with the dead scales which collect in the spaces between the toes, otherwise the feet rapidly become offensive. The other parts of the body which should be daily washed in addition to the hands, feet, and face, are those parts where perspiration is most active, namely, under the armpits, in the groins and perinæum (the fork and the space between the buttocks). The head should be thoroughly washed at least once a week.

A good deal of the soot and dust in the atmosphere of large towns is prevented from reaching the lungs by becoming lodged in the nasal cavities just within the orifices of the nostrils. The nose, therefore, performs the useful functions of a filter, but, like other kinds of filters, it should be periodically cleaned. This can best be done with a soft handkerchief and water, without soap, the nose being then well "blown" to displace accretions of mucus.

The Care of the Teeth.—Dental caries or decay is present in the teeth of quite 75 per cent. of school children. It is largely due

to the acids formed by fermenting carbo-hydrate food, retained between and around the teeth, gradually destroying the enamel covering of the teeth, and the subsequent attack of the dentine by micro-organisms. The importance of dental caries depends upon the fact that the condition often interferes with mastication, causes pain and loss of food, leads to the swallowing of pus and offensive breath, tends to impair nutrition (when extensive the physical measurements of children are generally below the average); and the appearance is disfigured. The circumstances which favour the condition are rickets, ill-health (acute disease and indigestion), oral breathing, heredity, and malnutrition; and the exciting causes are neglect to keep the mouth clean, malformed and irregular teeth, bad feeding (especially when the food is soft, starchy, and agglutinative), defective mastication, and the neglect of conservative dentistry.

Babies who have been breast-fed until they are nine months old are far more likely to have good teeth and well-developed jaws than bottle-fed babies. The continual sucking by babies of comforters or dummy-teats is very apt to produce deformities of the jaw and irregularity and crowding of the teeth. Such teeth decay early, and the deformity of the jaw remains throughout life, producing unsound teeth, adenoids, enlarged tonsils, and other serious troubles.

To develop the jaws properly, and to keep the teeth clean and free from the germs of decay, it is necessary that children of all ages, after their first set of teeth are cut at the age of about two years, should have food which they must bite and chew before they can swallow. Pappy and soppy foods, such as bread and milk, rusks and milk, mashed potatoes and gravy, are only suitable for little children between the ages of 9 months and 18 months. Even these little ones are the better for being given a crust of bread to chew every day or twice a day, so that the muscles of the jaws may be properly exercised. The crust should be given at the end of a meal.

After 18 months of age, a child should have at every meal something which it must bite and chew before it can swallow. It is only in this way that the jaws can be made to develop properly, and that the teeth can be kept clean. The best foods for this purpose are brown or wholemeal bread, both crust and crumb; crust of white bread; fish; meat—cut in small bits for a young child, but not minced; bacon, butter, margarine,

or dripping spread on bread crusts; baked potatoes, and potatoes boiled in their skins; cooked greens, carrots, and turnips; uncooked lettuce and cress; fresh fruits such as apples, oranges, bananas; and nuts.

The foods which require little chewing, and which cling to the gums and teeth after a meal, thereby tending to make the teeth decay, are the crumb of white bread; bread and milk; milk puddings, porridge and milk; sweet pastry; sweet biscuits; cake; marmalade, honey, and jams; chocolates and sweets.

When these pappy or sweet sticky foods are eaten at a meal, the child should be taught to rinse out its mouth with water after the meal is finished. The eating of pastry, biscuits, chocolates, and sweets between meals should be discouraged. Apples, oranges, and other fresh fruits are better for the teeth, and better for the children's health.

The cleansing of the teeth at night, before going to bed, with a tooth-brush helps to keep the mouth clean. Fermenting food between the teeth chiefly attacks the enamel at night, when there is but little saliva to wash away the acids formed by fermentation.

The tooth-brush should be used with an up-and-down motion on both sides of the teeth, as this displaces collections of food better than the side-to-side movement of the brush as usually practised. The rubbing of the gums with the brush need not be feared in healthy children, as it does them good, if not done too hard.

Children who are too young to use a tooth-brush should be taught to rinse out their mouths with water, before going to bed.

Every child would be the better for skilled supervision by a dentist from the time of commencement of the second dentition (6 years of age). In later life, however much care is taken of the teeth, it is unwise to neglect the dentist, as teeth vary much in their resistance to decay, and early attention may do a great deal to preserve sound teeth, which left to themselves become absolutely useless.

The Care of the Bowels.—Chronic constipation is one of the commonest of the minor evils of latter-day civilization. Whilst in some the tendency to weak digestive action and sluggish bowels is inborn and hereditary, in a vast majority the evil results from defective habits and mode of life. Relief is too often sought in drugs, and when the bowels have once become habitu-

ated to act only upon the stimulation of aperients, it is very difficult to acquire again the natural function.

The commonest causes of constipation can only be considered here, and they may be classified as (1) the failure to develop a regular habit of daily evacuation of the bowels at a stated time, whereby the bowels become habituated to develop their peristaltic movements in obedience to a regularly occurring stimulus —usually the entrance of food into the stomach at breakfast time after the night's fast. (2) A diet of food so highly digestible, as to leave but little residue in the large intestines. The fæces being deficient in bulk in the lower bowel, remain there too long, too much water is absorbed from them, and they become hard, scanty, and tenacious, and difficult of ejectment. There is but little to irritate and stimulate the inner lining of the bowel, with the result that the intestinal secretions are not properly exuded, and the peristaltic movements of the muscular coats are not effectually aroused or co-ordinated to secure the onward movement of the fæcal mass. On arriving in the rectum the fæces are so dry and hard, that great straining results in the attempt to defæcate, and the rectum fails to be properly evacuated. (3) Too sedentary a life, and want of proper exercise, lead to loss of tone in the muscular system, both voluntary and involuntary, with the result that the weakened muscles of the intestinal walls are not helped by strong contractions of the muscles of the abdominal walls, and there is a general tendency to stasis of the intestinal contents.

The remedies for such forms of constipation as are induced by any of the above conditions are fairly obvious. In the first place, regular habits of daily evacuation of the bowels should be formed. In the second place, the food should have sufficient bulk, and should contain a good deal of matter of the nature of cellulose or woody fibre, which being incapable of digestion or absorption in the stomach and small intestines passes down to the lower bowel, and so maintains suitable bulk in the fæces. Cooked vegetables and fruit, salads and raw fruits should be added freely to the diet for these reasons. Wholemeal bread should be taken instead of white bread, as the branny particles in the former pass through the intestines unaltered, and stimulate the secretion of the intestinal juices by irritation of the mucous membrane of the lower bowel.

Even if these measures do not succeed at once they should

be persevered with, and the use of aperients abandoned as soon as possible. The only aperient which is harmless to the bowel is refined paraffin oil, which is altered but little in its passage through the intestine, and lubricates the internal walls of the lower bowel and rectum, thus aiding evacuation of the fæces. Occasionally constipation appears to be connected with a deficiency of fat in the food, and the consequent failure of the food in its passage through the upper bowel to secure a sufficient secretion of bile and pancreatic ferments.

The exercises that are best adapted to overcome constipation are those which bring into play the muscles of the abdomen, chest, and back. All forms of running games are good for the young and active. For the middle-aged or old there is nothing better than judicious horse exercise, which is especially strengthening to the trunk muscles, and which also by its jerks and jolts effectually stimulates the circulation of blood in the abdominal organs, and greatly assists the passage of the intestinal contents through the lower bowel. For those who cannot afford to keep or hire horses, there are various forms of physical culture exercise that are suitable; whilst for the aged and infirm abdominal and general massage in skilled hands is often efficacious.

Tobacco.—The effects produced by the excessive smoking of tobacco have often been discussed. Of all the components of tobacco smoke, nicotine is by far the most important; the other components, including pyridine, are of little moment. Smoking raises the blood-pressure by vaso-constriction, accelerates the heart and respiration, and increases intestinal movements. Functional disorders of digestion and gastric catarrh, irritation of the pharynx, defective vision, nervous tremors, and dilatation of the heart, are all ascribed to excessive tobacco-smoking; and it is maintained by some that serious circulatory disorders, including arterio-sclerosis, may be produced. It is, of course, towards the end of a pipe, cigarette, or cigar, that most of the nicotine is taken into the system. The inhalation of the smoke from cigarettes (the swallowing of the smoke) is a pernicious habit when many cigarettes are smoked daily, and appears to be especially deleterious to youths. Excessive smoking may possibly lead to arrest of growth, before the body is fully developed, but the evidence of such arrest is naturally inconclusive, as defective development may be due to many other causes.

Youth, Middle Life, Old Age.—In the period of growth and development it is desirable that there should be a sufficiency of good and suitable food, proper exercise for the growth of all parts of the body, and sleep and rest sufficient for recuperation. As much time as possible should be passed in the open air, for development is liable to be arrested if during growth too much time is spent indoors.

In middle life commence the degenerative changes which are characteristic of senility. The later the period at which such changes commence, the longer is old age held in abeyance, and the vigour of the body maintained. The most important of these changes affect the heart and arteries. In many instances the gradual loss of elasticity and tone in the arterial coats appears to be related to a condition of high arterial tension, which is itself a neuro-muscular phenomenon, depending upon long-sustained mental or physical overstrain, upon chronic poisoning of the blood with alimentary toxins, or upon specific infections, such as pre-existent syphilis, or systemic poisons (alcoholism, plumbism, etc.).

The prophylaxis of this condition of high arterial tension must depend upon the cause. As it affects the majority, especially of males, it is a question of avoiding the overstrain so often associated with the rush and struggle and competition of modern life, of careful selection of diet as age advances and opportunities of exercise in the open air grow less, and of extreme moderation in alcohol. If business and professional men who have reached fifty years would realize that their nerves, their hearts, and their digestions are no longer those of youth, that prolonged work and worry are not to be counteracted by heavy meat meals, washed down by alcoholic stimulants to aid the weak digestive powers, the expectation of life at middle age, which is now decreasing as compared with twenty years ago, would tend to rise again.

In old age, strain and excitement should be avoided. The heart and arteries at their best are little able to bear shock and strain, and the bodily functions are only performed with ease if the work the organs are asked to do is adjusted to their failing powers. The avoidance of chill and exposure is very essential, for the bodily powers are easily depressed, and reaction is slow in the old.

Fatigue.—It is essential that workers should realize that the physiological laws of life must be obeyed if the best results are

to be obtained; and it is a problem of scientific management to discover, in the interests both of output and health, the working efficiency of the various faculties of the human machine.

It is fallacious to take the bodily sensations even as a guide, much less as a measure of fatigue, for there may be diminished capacity for work before any signs of fatigue appear in sensation. Fatigue results not only from the exhaustion of substances supplying chemical energy for work, but from the accumulation of the (waste) products of the chemical changes. These chemical products of activity are removed by the blood from the tissues, and time is required both for this removal and for their subsequent excretion from the body. Since the nerve cells are liable to fail from exhaustion, before the muscles become affected, the problems of industrial fatigue are almost wholly problems of fatigue in the nervous system.

An important and early sign of fatigue is a want of co-ordination and failure in the power of concentration. This may be shown objectively in an increased frequency of trifling accidents. The accumulative results of fatigue damage the general health and are reflected in sickness returns, in returns of lost time, and unsatisfactory quality and quantity of output. The stale and tired feeling may result in a craving for change and excitement, and may lead to over-indulgence in alcohol.

A good deal of fatigue is in evidence when long spells of continuous work are demanded. This is true even when due allowance is made for the effects of high temperature in the workrooms, the sex and age of the workers, the nature of the work, the monotony of many forms of work, the lighting conditions, noise, warm moist atmospheres, etc. The available tests of fatigue in practice are the output of work and the accidents (of psycho-physiological origin) occurring in the course of work, the proportion of mistakes or spoilt work, and medical reports of conditions of ill-health attributable to overwork.

Any standard of work determined should be one that a man or woman can attain to, day in and day out, without injury to his or her health of body or mind. The importance of adapting properly the hours of labour to each kind of work is very great. The shortening of unduly long hours has the effect of reducing the amount of spoiled work, while maintaining the quantity of output, and the health and sobriety of the workers is improved.

CHAPTER VIII

FOOD, BEVERAGES, AND CONDIMENTS

FOOD.

THE purposes fulfilled by food may be defined to be as follows:

1. To form new tissues in the process of growth.

2. To repair and renew the wasted tissues—solid and fluid—of the body.

3. To provide the material which serves as fuel to the body, and which, by its combination with oxygen, is reduced to the simpler forms of urea, carbonic acid, and water, thus supplying the sources of animal heat and the manifestations of energy which are essential for the maintenance of life.

All the various food substances and proximate constituents of food may be classified broadly under two heads—as nitrogenous and non-nitrogenous.

The proteins, which are substances allied in chemical constitution to albumin, form a large proportion of the nitrogenous food substances, whilst the non-nitrogenous substances consist of the fats, the carbo-hydrates, the vegetable acids, the mineral salts, and water.

Proteins.—The average composition of proteins or albuminoids may be taken as being approximately as follows: In 100 parts—nitrogen, 16; carbon, 54; oxygen, 22; hydrogen, 7; sulphur, 1. The proportion of nitrogen to carbon is nearly in the ratio of 2 to 7. In gelatine the N is about 18 per cent. In the process of digestion proteins are converted into albumoses and soluble peptones, which are highly diffusible and capable of passing through the inner coats of the alimentary tract into the blood and lymph streams. A part of the peptones is further transformed into leucin and tyrosin, but the final products derived from protein food are carbonic acid, water, and urea. Peptones differ from common albumins in being soluble, uncoagulable by heat, acid, or spirit, and in being dialyzable.

Nitrogenous foods are essential for the maintenance of animal life. All organized animal structures contain nitrogen, and there can be no chemical change and no manifestation of energy in any animal tissue from which nitrogen is absent. Consequently nitrogenous foods are required for the formation of new and the repair and renewal of old tissues, and for the formation of the digestive and other fluids of the body. The nitrogenous tissues of the body are also the regulators of the absorption and utilization of oxygen, by which energy is manifested; therefore the proteid foods, which make and repair the tissues, also participate in this regulation of oxidation and energy. They are also supposed to have another function under certain special conditions, viz., the formation of fat and the yielding of energy; but of this little is known, and doubtless the main source of energy is the oxidation of non-nitrogenous substances. Under a diet from which nitrogen is withheld the body languishes; the functions are carried on at the expense of the existing tissues and structures, and these undergoing no renewal, death must eventually result.

The proteins for the most part are of nearly equal nutritive value, and are therefore mutually replaceable in a diet. This applies to the different members forming the animal protein class and to the vegetable and animal proteins taken as two separate classes. The only advantage in favour of animal nitrogenous food as opposed to vegetable is that the former has a higher biological value, and is more rapidly and completely digested. Protein substances are split up in the processes of healthy digestion, either in part or whole, into metabolic products, which are potentially poisonous to the system. These bodies are, no doubt, under conditions of normal health and activity, disposed of in the system without detriment to its vital functions; but if they are produced in excess, or more rapidly than they can be destroyed or eliminated, as may happen after a meal of meat excessive in amount, they tend to accumulate in the system, and may be the cause of that heaviness and languor so frequently experienced by large meat eaters, especially by those of a dyspeptic habit.

These metabolic products of proteins, when soluble, are taken into the blood, and transported to the liver. Here they are transformed into substances essential for the nutrition of the body, unless present in too large an amount or in an unsuitable form. In such an event symptoms of alimentary toxæmia

supervene. It seems probable that the thyroid gland is also concerned in the process of counteracting the injurious effects produced by circulation in the blood of proteoses and bacterial toxins. The circumstances favouring alimentary toxæmia would appear to be, therefore, either (1) unsuitability of food, (2) defective conditions in the small or large intestine, or both, inducing an excess of the metabolized products of proteins in the food, which are poisonous to the body (indol, skatol, phenol, cresol, etc.), and (3) changes in the liver, which prevent its performing its proper function of a transformer of proteins. It has been thought by some that stasis of the intestinal contents in the cæcum and colon, owing to mechanical derangements (adhesions, prolapses, kinks, dilatations, and contractures), are the chief cause of the production of toxic products in the bowels from bacterial fermentations.

As gelatine, ossein, etc., are not the nutritive equals of the other proteins, they cannot replace them. Gelatine is easily oxidized in the body, and appears to be of value in cases of acute disease, when given in the form of jellies, in preventing excessive tissue waste. In such cases the proteins, if given, may not be digested or assimilated. Gelatine cannot build up or repair nitrogenous tissues, for it lacks certain of the essential amino-acids; but it can take the place of part of the nitrogenous substances in the blood which undergo oxidation, and is of equal value to protein as a source of energy.

The Influence of Bacteria on the Digestive Processes.—The part played by bacteria in the digestive processes is not fully understood, but what is known may be briefly summarized. Large numbers of organisms—chiefly streptococci—are contained in the secretions of the mouth, but what part these take in salivary digestion is not known. Very few bacteria are normally present in the stomach and duodenum, the acidity of the gastric juice in health being unfavourable to the growth of most organisms, and the periodical emptying and scouring of the stomach tending to their elimination. If the stomach is dilated, and its contents are unduly retained, yeasts, sarcinæ, and other organisms tend to multiply, fermentation ensues, and health is disturbed.

In the small intestine bacterial multiplication increases as the cæcum is approached. The action of the bile is to favour the increase of *B. coli* and allied organisms, whilst streptococci and *B. proteus* are restricted. In the colon the bacterial multi-

plication is greatly increased, owing to the slowing down of the rate of movement in the intestinal contents. The predominant organisms here are the members of the *B. coli* group and streptococci, *B. coli* being usually the more numerous (Andrewes). The conditions in the large intestine are very largely anaerobic, owing to the absence of oxygen; and, in consequence, the digested food is here subjected to changes of a far-reaching nature, proteins especially being broken down to a point beyond that which the body demands for its own nutritional needs, and certain of the products which thus arise are actually harmful (Andrewes).

On the whole, it may be concluded that whilst in health the bacterial flora of the lower intestines have a useful effect in breaking down proteid residues to a point beyond that which can be exercised by the ordinary digestive ferments (enzymes), and so enabling a larger proportion of proteid material to be absorbed from the bowel than would otherwise be the case, still this process has certain drawbacks, especially the undue production by anaerobic organisms of soluble toxic products in excess of the capacity of the liver, kidneys, and ductless glands to render harmless to the body generally. There is at present a school of medical opinion which is inclined to regard the lower bowel as the place of origin of many of the chronic disorders which lead to chronic invalidism, premature old age, and early death.

Whilst there is not sufficient evidence to prove that vegetarianism, so-called, is more conducive to health or longevity than a mixed diet, there can be but little doubt that the wealthier classes eat too largely and too frequently of meat. During growth a purely vegetarian diet is inadequate, as the vegetable proteins are deficient in the amino-acids so necessary for growth and repair. Excess of nitrogenous food causes not only an abnormal production of the poisonous bodies, of whose potentialities for evil but little is at present known; but an excess of nitrogenous waste accumulates in the blood, oxidation is interfered with, the liver, the kidneys, and the other excretory organs are overtaxed in their work of eliminating waste substances, which are also insufficiently elaborated, and gout or liver and kidney disease result.

Overaction of the liver, kidneys, and other excretory organs, persisting with little variation over long periods of time, and the resulting retention of partly elaborated and toxic waste

matters in the blood, furnish the conditions which are known to be causative of degenerative changes in the tissues, and which lead in middle life to many chronic diseases of important organs, and maybe to death at an age when impairment of functional activity should hardly have commenced.

The *extractives*, such as those contained in the juice of flesh, can neither build up tissue, nor serve as fuel, but they appear to act as regulators and stimulants of digestion and assimilation, especially when gelatine and allied bodies are comprised in the diet. Hence the use of beef-tea, which, as usually made, contains little beyond extractives in the dietary of sickness.

Hydrocarbons or Fats.—These bodies are compounds of glycerine with the fatty acids—oleic, stearic, palmitic, etc. They contain no nitrogen, but are made up of carbon, hydrogen, and oxygen, the proportion of oxygen being less than sufficient to form water with the hydrogen present. The fats are unacted upon by the saliva and by the gastric juice, and pass through the stomach unchanged; but in the small intestine they are emulsified by the pancreatic juice and bile, and rendered capable of absorption by the lacteal vessels, whilst a small portion is saponified —*i.e.*, split up into glycerine and fatty acids, the latter uniting with alkalies to form alkaline palmitates, oleates, and stearates (soaps), which are directly absorbed into the blood or lacteals.

Fat is digested and absorbed more slowly than carbo-hydrate; on this account a meal lacking in fat may be deficient in staying power.

The chief function of the fatty foods is to repair and renew the fatty tissues, and to yield energy and keep up the animal heat by oxidation into carbonic acid and water. The presence of the fats in food promotes the flow of the pancreatic juice and bile; they thus help in the proper assimilation of other foods, and assist the excretory functions of the intestine, which are badly performed if bile and the other digestive fluids are not secreted in sufficient quantity.

As fat yields, weight for weight, more than twice as much energy as carbo-hydrate, it is largely consumed in cold countries. In the diet of an infant at the breast fat gives over 50 per cent. of the total energy.

The animal fats are more easily digested and absorbed than the vegetable. If there is excess of fat in a diet, it passes out unchanged in the fæces.

Carbo-hydrates.—These substances are made up of carbon, hydrogen, and oxygen, the oxygen being present in the exact proportion necessary to form water with the hydrogen present. In the process of digestion, starch, cane sugar, dextrine, and milk sugar are converted into grape sugar. This change is commenced in the mouth, during the process of mastication of the food, by the action of the saliva; it is not carried any further in the stomach, but is completed in the small intestine by means of the pancreatic juice. The starch ($C_6H_{10}O_5$) takes up a molecule of water to become grape sugar ($C_6H_{12}O_6$), which is taken up by the blood and carried by the portal vein to the liver, where it is deposited as glycogen or liver starch. The liver acts as a store-house for the deposition and accumulation of these converted starchy foods, which are subsequently supplied to the system as the needs of the economy demand, there to undergo oxidation for the manifestation of heat and energy, and to be used for the building up of the fatty tissues of the body.

The functions of the starchy foods are thus seen to be the production of animal heat and energy by oxidation, and the formation of new fatty tissues.

The fattening caused by a diet rich in starch and sugar may partially be due to the oxidation of these substances saving the fatty tissues from destruction, and allowing the fat in the diet to form new fatty tissues.

Although the functions of the fats and carbo-hydrates in the economy are very much the same, they are not mutually replace-able under ordinary conditions, if health and vigour are to be maintained at their maximum. In the absence of carbo-hydrates the proteins are attacked and carbo-hydrate is split off from the protein molecule, or synthetized from the oxy-fatty acids result-ing from the primary decomposition of the amino-acids. A diet in which fat takes the whole place of carbo-hydrates produces acidosis, the oxidation of the fats being defective in the absence of carbo-hydrates. Where men are much exposed to very cold temperatures and undergo great fatigue in the open air—as during Arctic expeditions—a diet of proteins, fats, salts, and water (without carbo-hydrates) may maintain them for a time in good health; but the deprivation of fat from the diet under any circumstances is not well borne and leads rapidly to loss of health and vigour. Moreover, fat in the diet stimulates the flow of bile, increases intestinal movements, and pro-

motes the passage of chyme through the intestinal mucous membrane.

The absence of fat in a diet leads to a state of malnutrition, possibly predisposing to such diseases as tubercle, especially in children and young persons. The deprivation of starches can be borne for a long time if fat is given; but little is known as to the ultimate effects of such deprivations, for wherever food can be obtained at will, the starchy constituents, so widespread and abundant in Nature, are sure to be largely represented.

It also appears that the carbo-hydrates are concerned with the maintenance of the proper reactions of the various body fluids (blood, lymph, gastric juice, urine, etc.). They give rise to lactic and other similar acids in the body, which act upon the alkaline phosphates, chlorides, etc., and elaborate the various acid juices characteristic of the different bodily secretions and excretions. Starches and sugars have much the same dietetic value. Cellulose is only to a slight extent converted into sugar by the human digestive process, consequently much passes out unchanged in the fæces.

It is evident, therefore, that a diet which is to maintain proper bodily health must contain all the three substances—proteins, fats, and carbo-hydrates. The albuminoids are the most indispensable, as without them vital action must cease for want of a supply of nitrogen. But a diet of proteins, salts, and water alone is rapidly destructive of healthy action. As before explained, the excessive waste resulting from the metabolism of so much nitrogenous food, necessary to maintain animal heat and energy, overtaxes the system, and imperfectly oxidized substances accumulate in it, which pervert healthy action and eventually set up diseased conditions.

Organic Acids.—These exist in fresh vegetables and fruit, probably also in fresh meat and milk in combination chiefly with alkalies as alkaline salts. These acids form carbonates in the system, and preserve the alkalinity of the blood and other fluids. This is their chief function, but they may also furnish a small amount of energy and animal heat by oxidation. If these substances are absent in a diet, the blood becomes impoverished, and scurvy results. There is evidence, however, that fresh vegetables or lime juice are not alone sufficient for the prevention or the cure of scurvy, and that the disease may be due to poisoning by the ptomaines of tainted animal food, or by bodies

of unknown composition present at times in tinned or preserved animal foods, which are apparently in good condition and free from putrefactive taint.

Vitamines.—Modern research on metabolism has shown that a diet of pure protein, fat, and carbo-hydrates, with due admixture of salts and water, is not sufficient to maintain health, though the quantities given may be theoretically correct. Hopkins fed a number of rats on an artificial diet of proteid, fat, starch, and sugar; and by appropriate observations he found that the rats fed upon this synthetic diet ceased to grow, while the intake, quantitatively, exceeded that necessary to maintain normal growth. By the addition, however, of a small quantity of milk to this diet, a marvellous improvement in the health and growth of the rats became evident. The improvement was not due to the lact-albumin or salts contained in the milk, as an equal rate of growth was obtained from protein and ash-free extracts of the milk solids, and from yeast, in exceedingly small quantity. Hopkins, therefore, concluded that there is some factor in diet, other than its protein and energy content, which is indispensable to health and growth.

Other recent researches have shown that beri-beri, polyneuritis, and scurvy, possibly rickets, sprue, and pellagra, may result from a deficiency of certain substances in the food, minute in amount, but essential to nutrition—hence these diseases have been styled "Deficiency Diseases." It appears that even in some cases where these factors are present, but where the diet is limited and unvaried, and the individual is without appetite and proper assimilation, a deficiency disease may develop. It is not held that these substances are in themselves nutritive; it seems more probable that they act as "activators" in the utilization of food-stuffs by the tissue and cells of the body. Thus the anti-rachitic vitamine appears to play a part in the prevention of rickets by enabling the body to make use of the calcium at its disposal. Funk gave the name "Vitamines" to these factors. Their chemical nature is unknown. The small fraction of vitamines usually yielded by articles containing them is a serious difficulty in the way of elucidating their nature and composition. There are vitamines necessary for the maintenance of nutrition, and others necessary for growth; moreover, they are believed to have a reaction on the functions of the important secretory glands.

The substitution of polished rice for the whole grain has been proved to be the cause of beri-beri. When the polishings are added to the diet, or the natural rice substituted for the polished, beri-beri is cured. The vitamines in the cereals, including wheat, oats, maize, and barley, are also contained exclusively in the outer coat. The observations of Hopkins, Hill, and Flack show that a diet of wholemeal bread and water suffices to keep pigeons, mice, and rats in health; but the process of milling removes the vitamine, and so these animals cannot exist for more than a few weeks on white bread and water. The amount of vitamines in milk has been shown to be influenced by the food of the cows; their food in winter may be poor in vitamines, and the milk may then contain almost none. Pellagra is attributed by Funk to the polishing of maize, which removes the husk or outer coat (*vide* Chap. IX.).

The anti-beri-beri vitamine is soluble in water, and alcoholic extracts may be prepared containing them. Such extracts added to polished rice, maize, or white flour improve these foods *qua* vitamines, but they do not replace all that is in the whole grain.

During the Great War, in Mesopotamia, scurvy was quickly stamped out from the Army when it became possible to make a regular issue of fresh vegetables and meat. Likewise beri-beri in British troops ceased with the issue of such articles as Marmite (extract of yeast), oatmeal, lentils, and bread containing wholemeal wheat-flour.

Biological experiments have established the existence of three classes of vitamines:—

(1) Fat-soluble A, the anti-rachitic factor.
(2) Water-soluble B, the anti-beri-beri factor.
(3) Water-soluble C, the anti-scorbutic factor.

A and B are both resistant to heat, while C is unstable to heat and alkalies, and it disappears as food ages.

The animal world is dependent upon the vegetable kingdom for a supply of these three vitamines; but they may be stored up in animal tissues, and animal fats are the chief source of supply of the fat-soluble A vitamine. For the other two vitamines the best source of supply is fresh vegetables.

Vitamines are distributed very unevenly, both as to their presence and amount, in the usual food-stuffs. They are specially

to be found in milk, butter, whole-milk cheese, cream; fresh meat, liver, kidneys, heart, brain of animals; fat fish, eggs, dripping, and cod-liver oil; wheat (wholemeal), germinating grain, peas, beans, lentils, and potatoes; all forms of fresh green leaves—cabbage and spinach when these are steamed and not brought to the boil, lettuce, carrots; dessert fruit, including nuts, lemons, and lemon juice; fresh yeast and its preparations, and certain forms of malt extract.

Vegetable fats contain very little vitamine A, and therefore the replacement of animal fats by the cheaper vegetable fats in human food prejudices the adequate supply of vitamine A in the diet. For this reason the giving of the poorer children margarine instead of butter is not desirable, for in their case other articles of food containing this vitamine may not be given in sufficient amount. It is not enough to provide that these accessory factors are present in diet; they must be present in sufficient quantity.

Foods are robbed of vitamine not only by modern milling processes, but also by superheating in the process of canning, and by boiling and stewing if the water is thrown away.

Scurvy.—Land scurvy is a disease of war-devastated areas and of famine-stricken populations. Scurvy is also liable to occur at sea on ships on long voyages, where all kinds of fresh food have been consumed, and the diet is limited to salt, preserved, or canned foods. The same conditions are apt to arise in Arctic and Antarctic expeditions, unless great care is taken in the choice of provisions. There is generally a pre-scorbutic stage of varying length, characterized by depressed vitality and early fatigue and listlessness, accompanied by bowel trouble. This stage is succeeded by a toxæmic stage, marked by profound depression, swollen and bleeding gums, loosening of the teeth, and gastro-intestinal disturbances with congestive and hæmorrhagic lesions causing toxic absorption from the bowel. The endocrine glands are affected.

Predisposing influences are cold, fatigue, mental depression, short rations, crowded and dirty surroundings, and individual idiosyncrasy.

The immediate cause of scurvy is absence or deficiency in the diet of the water-soluble C vitamine. The chief prophylactic measure, consequently, is the exhibition in the daily dietary of food substances which contain this vitamine in

notable amount. Such prophylaxis will not only prevent the onset of scurvy, but will arrest the disease, and restore to health, if the vital energies have not been too far undermined. The following substances have anti-scorbutic properties:—*Lemon juice*.—This has now displaced the time-honoured lime juice, which was found to be very inefficient. Lemon juice is very rich in active vitamines. The fresh juice may be dried *in vacuo* over sulphuric acid, leaving a viscid syrupy mass which may be preserved by the addition of 10 per cent. alcohol, which also prevents freezing (Admiral Bassett-Smith's process). The anti-scorbutic value is well retained. The dose daily per man should be the equivalent of half a lemon in the fresh state. *Orange juice* is only slightly less effective than lemon juice, and may also be prepared as a dried product. *Cow's milk*, fresh from cows fed on grass and green-stuff, has some anti-scorbutic properties, but not when the cows are fed on grains and oil-cake. *Dried milk* is also anti-scorbutic, if prepared by the Just-Hatmaker process, where the milk is heated on revolving drums to a temperature of not over 100° C., and the film formed on the drums is scraped off within a few seconds by a knife-edge into a container. In the spray process of drying milk the water-soluble C vitamine appears to be destroyed. Of course, all dried milk should be prepared from the milk of grass or green-stuff fed cows. *Vegetables and Fruits*.—Most fresh vegetables and fruits are highly anti-scorbutic, but are less so when cooked. Dried and canned vegetables and fruits are of little value, with the exception of canned tomatoes. Fresh tomatoes boiled for an hour only lose 50 per cent. of the water-soluble C vitamine. *Pulses and Cereals*.—These, when allowed to germinate in water, contain the vitamine in active condition, but are indigestible, unless very lightly cooked. *Meat*, when recently killed and cooked, is anti-scorbutic, but a good deal must be eaten if the diet is otherwise wholly deficient in anti-scorbutic vitamine. Dried, preserved, canned, and salted meats and fish have no anti-scorbutic value.

Rickets.—There is no general agreement about the etiology of rickets, but the latest researches tend to show that the disease is a "deficiency" disease, like scurvy and beri-beri, the missing factor in the diet being the fat-soluble A vitamine, which is present in all animal fats, except lard, in some fish fats, and a few vegetable oils.

By some the condition known as acidosis has been claimed to have a connection with deficiency diseases, such as scurvy, beri-beri, and rickets. In consequence of the excess of acids in the system, calcium is withheld from the growing bones, as it is more urgently required to neutralize the acid products of incomplete combustion, and so escapes in the excretions, instead of forming the bony tissues.

The disease is one of infancy and early childhood, usually commencing between the first and second years, but leaving after-effects in the way of deformities of the bones and joints which may persist throughout life. There is a failure in calcification and ossification of one or more of the long bones, the skull, and the ribs; the epiphyses of the bones are soft and swollen, the periosteum is thickened, and the medullary material is in excess. The bones, being soft, become curved and bent, and later on ossify in their abnormal curves, causing permanent deformities. Children sometimes develop rickets, although the diet contains enough fat for the requirements of organic growth; but in such cases it will generally be found that there is an excessive amount of carbo-hydrates in the food, such as may be produced by the use of sweetened condensed milk. The excess of sugar leads to acidosis and chronic digestive troubles, which interfere with the proper absorption of fat. Such digestive troubles may also arise from faulty "mothering," as evidenced by over-clothing, lack of sunlight, air, and exercise, overcrowding in the home, unsuitable food, and uncleanliness, these conditions being often noted in rickety families, and being regarded as the primary causes, whereas they may be only the factors which produce the gastro-intestinal disturbances leading to the faulty assimilation of fat.

American researches tend to show that daily exposure to sunlight inhibits the bony changes which are produced by a diet deficient in vitamine A in the absence of sunlight. This effect of exposure to sunlight is not yet understood, and its relation to the inhibition of rickety changes in the bony tissues requires further elucidation.

The researches of Dr. and Mrs. Mellanby have placed the theory of rickets as a deficiency disease on a strong experimental basis. They also show that in puppies defective development of the jaws and the teeth follows upon a diet from which fat-soluble A vitamine is absent. In these animals a diet of separated

milk, white bread, and lean meat, which contained yeast (anti-neuritic), and orange juice (anti-scorbutic), but no fat-soluble A vitamine (anti-rachitic), resulted in comparatively soft and poorly developed jaws and alveolar processes; teeth, chiefly lower incisors, crowded together; delay and slowing in the eruption of teeth; delay and defective calcification of the teeth; deficient dentine; and light teeth for their size with low calcium content.

Although rickets is usually first noticed in children over a year old, a well-marked tendency to rickets (incipient rickets) is often seen in infants between six months and one year, even although breast-fed. This appears to be due to the mother's diet being deficient in animal fat during pregnancy and lactation. The poorer class of mother generally eats margarine (often largely composed of dried vegetable oil) instead of butter, meat is but seldom taken, bacon is too dear, as also is milk in sufficient quantity, and dripping is difficult to obtain. It is especially to this class of mother and her infant that the supply of milk free, or at less than cost price, under the Milk (Mothers and Children) Orders has been so beneficial during the period of high food prices following the war.

The following foods contain fat-soluble A vitamin in notable amounts: cod-liver oil, whole fresh milk and cream, butter, beef and mutton fat, margarine and dripping made from animal fats, yolk of egg, some vegetable oils. Fat-soluble A vitamine is not much affected by heat, unless the heat is prolonged, consequently lightly boiled milk and dried milk are but little less anti-rachitic than fresh unheated milk.

In the prophylaxis of rickets and the treatment of actually rickety conditions, the part played by gastro-intestinal derangement must not be lost sight of. The diet must be re-arranged on physiological lines and excessive carbo-hydrates eliminated, so as to prevent acidosis and allow proper absorption of fat; and all digestive disturbances must be controlled before the addition of fats to the diet containing the necessary anti-rachitic vitamine can be expected to result in complete restoration to health. It is evident also from the American experiments that exposure to light for as long as possible every day is a prophylactic measure of considerable importance in cases where the dietary is not obviously deficient in vitamine A.

Hunger Osteomalacia.—This is a disease which was prevalent

in Vienna in the winters of 1918 and 1919, as a result of the conditions of semi-starvation then existing. It occurred amongst the poorest inhabitants, affecting chiefly middle-aged and old people of both sexes. The characteristic symptoms are pain on bodily movement, a waddling gait, difficulty in mounting stairs, severe pain in the sacral region on pressure or movement, and pain in the ribs on compression of the thorax. The disease is of dietetic origin. The addition to the diet of sugar and cereals (*i.e.*, extra calories without fat) produced little improvement, although in many instances the previous diet had been very deficient in calories. Recovery followed upon the addition to the diet of either cod-liver oil, butter, oleo-margarine containing 80 per cent. of animal fat, or olive oil. Cod-liver oil was the most effective, some of the severer cases not improving until cod-liver oil was given in doses of 60 grammes daily. The relative therapeutic value of the fats corresponds roughly with their contents in fat-soluble A vitamine. The lesser prevalence of hunger osteomalacia in summer may have been due to the inclusion in the diet of the summer months of green vegetables, which contain a certain amount of this vitamine. The increase in Vienna of rickets in children and late rickets in young adults simultaneously with osteomalacia is suggestive of all these disorders being due to the same cause (Dalzell and Chick, Hume and Nivenstein).

The *mineral salts* are essential for the growth and repair of all the tissues of the body. The phosphates of lime, potash, and magnesia contribute largely to the formation of bone; whilst iron for the red blood corpuscles and colouring matters, chlorine for the gastric juice, potash for the blood cells and solid tissues, and soda for the intercellular fluids, are all indispensable. Mineral salts are required in diets for all ages, but more especially for infants and children, when not only has waste to be made good, but new material for the growth of the body has to be supplied.

Water is a component part of all the so-called solid foods, and is likewise taken separately, the amount of water contained in the solid foods of an average diet being insufficient for the needs of the body. The water contained in different food-stuffs varies within very wide limits; in some articles it amounts to not more than 12 per cent. by weight, while in others it may exceed 90 per cent. Water is necessary to make up the losses occasioned by its excretion in the breath, sweat, urine, and fæces, and to renew

all the various fluids and solid organs of the body, into whose constitution water largely enters. Water also serves as a vehicle for the solution and dilution of the solid foods, whereby they are more easily digested and assimilated, and it is essential for the elimination of many waste products.

The Digestibility of Food.—Not very much is known of the digestibility of different kinds of food under varying conditions, but the following facts have been ascertained:—The protein of the ordinary table meats, fish, and milk is very readily and completely digested. The protein of vegetable foods is much less completely digested than that of animal foods. As much as a third of the protein of beans, for instance, may escape digestion, and thus be useless for nourishment. Much of the fats of animal food at times fails to be digested. The carbohydrates of vegetable food, with the exception of cellulose, are in general very digestible.

Diet.

From physiological experiment and actual experience, dietaries of different kinds, suitable for an adult under varying conditions, have been constructed; but there is considerable discrepancy among physiologists regarding the qualitative and quantitative composition of these diets. Thus, there is a subsistence diet, calculated as sufficient for the internal work of the body alone; a diet for light work (entailing the expenditure of energy equivalent to 300 foot-tons per diem); and a diet for laborious work (450 to 500 foot-tons daily)—all suitable for a man of average size and weight (150 pounds). The following table is compiled from the researches of Playfair, Moleschott, Pettenkofer, Voit, and Ranke:

	Subsistence.		Ordinary Work.		Laborious Work.	
	Oz. av.	Grammes.	Oz. av.	Grammes.	Oz. av.	Grammes.
Proteins	2·0	57	4·5	127	6·5	184
Fats	1·0	28	3·5	99	4·0	113
Carbo-hydrates ..	12·0	300	14·0	397	17·0	482
Salts	0·5	14	1·0	28	1·3	37
Total water-free food	15·5	399	23·0	651	28·8	816

The quantities specified represent dry food. Ordinary solid food contains on an average 50 or 60 per cent. of water, so that the quantities tabulated must be rather more than doubled in actual practice. About 50 to 80 ounces of water are in addition taken into the system daily in a liquid form, the quantity depending upon the amount of exertion undergone and the temperature and humidity of the air. Thus, for subsistence a man requires about $\frac{1}{10}$ ounce of water-free food for each pound of body weight, and for ordinary work about $\frac{1}{7}$ ounce.

From the above facts, and with the assistance of the following table (which shows the approximate percentage composition of some of the more ordinary articles of food), it is possible to calculate a diet consisting of some of these common foods.

Articles of Food.	Protein.	Fat.	Carbo-Hydrates.	Energy Value per Kilo, in Calories.
CEREALS:				
Wheat flour	11·4	1·0	75·1	3,639
Oatmeal	16·1	7·2	67·5	4,098
Barley meal and flour	10·5	2·2	72·8	3,620
Maize meal	7·5	4·2	65·9	3,400
Rice	8·0	0·3	79·0	3,595
MEAT:				
Beef	14·5	22·5	—	2,687
Veal	15·6	6·3	—	1,227
Mutton	13·5	25·0	—	2,879
Lamb	15·2	18·6	—	2,353
Pork	10·0	40·0	—	4,130
Bacon	9·5	59·4	—	5,914
Hams	14·5	33·2	—	3,682
Meat (preserved)	25·5	22·5	—	3,138
Poultry, game, and rabbits ..	20·7	8·3	—	1,621
Meat offal	20·0	10·0	—	1,750
Lard	2·2	94·0	—	8,832
Olive oil (refined)	—	100·0	—	9,300
DAIRY PRODUCTS, EGGS, ETC.:				
Milk	3·3	4·0	5·0	712
Condensed milk, sweetened ..	8·8	8·3	54·1	3,351
,, ,, unsweetened ..	9·6	9·3	11·2	1,718
Cheese	25·0	30·0	2·4	3,913
Margarine	1·2	83·0	—	7,768
Butter	1·0	85·0	—	7,946
Eggs	11·9	9·3	—	1,353

Articles of Food.	Protein.	Fat.	Carbo-Hydrates.	Energy Value per Kilo, in Calories.
VEGETABLES:				
Potatoes (20% allowed for waste)	1·8	0·1	14·7	686
Onions (10% ,, ,,)	0·5	0·1	5·5	255
Tomatoes	0·9	0·4	3·9	234
Peas, beans, lentils (dried) ..	24·3	1·3	60·3	3,590
Peas, green, in pods (45% waste)	3·6	0·2	9·8	568
Beans, ,, ,, ...	4·7	0·3	14·6	819
Carrots (20% waste)	0·9	0·2	7·2	351
Parsnips (20% ,,)	1·3	0·4	10·8	533
Turnips (30% ,,)	0·9	0·1	5·7	280
Green vegetables (15% waste) ..	1·6	0·4	4·2	273
FRUIT:				
Apples (25% waste)	0·3	0·3	10·8	483
Bananas (35% ,,)	0·8	0·4	14·3	656
Oranges (27% ,,)	0·6	0·1	8·5	382
Nuts	6·4	22·5	5·2	2,569
Fruit, dried	2·3	2·2	70·9	3,206
SUGAR AND MOLASSES, ETC.:				
Sugar, refined	—	—	100·0	4,100
Molasses, cane	2·4	—	63·0	2,680
,, beet	—	—	50·0	2,050
Cocoa and chocolate	15·0	26·0	30·0	4,263
FISH, FRESH:				
Herring (42·6% waste)	11·2	3·9	—	822
Haddock and cod (52% waste)..	8·4	0·2	—	363
Mackerel (44·7% waste)	10·2	4·2	—	809
Salmon (34·9% ,,)	15·3	8·9	—	1,455
Eels and congers	14·8	7·2	—	1,277
Shell-fish	5·2	1·6	0·51	383
FISH, CANNED, CURED, ETC.:				
Sardines	23·7	12·1	—	2,097
Salmon	19·5	7·5	—	1,497
Lobsters	18·1	1·1	0·5	865

The Food War Committee of the Royal Society concluded (1916) that the dietary requirements of those engaged in active work cannot be satisfied by less than 100 grammes protein, 100 grammes fat, and 500 grammes carbo-hydrate, approximating to 3,400 calories per diem.

The amount of nitrogen in the diet for ordinary work is 315 grains (20·4 grammes), and the amount of carbon 4,790 grains (310·4 grammes).

In the best diets the proportion of nitrogen to carbon should be about as 1 to 15.

The *energy* obtainable from the different articles of food is expressed as so many foot-tons per ounce consumed. It is the amount which would be produced if the constituents of the food were completely oxidized; and the energy derivable on this hypothesis from different food-stuffs can be calculated from the heat—as measured in a calorimeter—required for their complete combustion. It is evident, however, that such theoretical expressions may have a limited bearing upon dietetic value, which depends so largely upon the digestibility and assimilation of different food products; and that the whole of the potential energy thus calculated is therefore not available. In the case of proteins also, a portion passes out of the animal system incompletely oxidized in the form of urea. The figures usually given are:

One ounce of dry protein yields 173 foot-tons of potential energy.

One ounce of fat yields 378 foot-tons of potential energy.

One ounce of dry carbo-hydrate yields 135 foot-tons of potential energy.

According to these figures, the average daily diet for light work would yield 3,977·5 foot-tons, or in round numbers close upon 4,000 foot-tons; but a large proportion of this total energy, viz., about 2,500 foot-tons, is devoted to the maintenance of the body temperature, and to the performance of the various bodily functions, when the body is in a state of rest.

The question of how much energy is required has been investigated by keeping a person in a closed chamber, so arranged that the energy used is measured in heat units or calories by determining the heat given off, while the combustion going on in the body is measured by the products of combustion which are excreted, *e.g.*, carbonic acid and water in the breath.

By placing a person who has had no food for twelve hours in such a chamber it has been found that a man of average size, say 11 stone, while at rest evolves energy at about the rate of 70 calories per hour, or 1,680 calories in twenty-four hours. The taking of food involves increased work by the organs of digestion, and consequently an increased expenditure of energy, which has been estimated at 168 calories per twenty-four hours, raising the total expenditure to 1,848 calories for a man at rest in bed. Simply sitting up in bed causes a further increase of 8 per cent., raising the expenditure to about 2,000 calories, while

for an absolutely sedentary life indoors 2,168 calories are wanted.

In a state of rest, a man of 150 pounds weight gives off about 17 cubic feet of CO_2 gas in twenty-four hours. The production of 1 cubic foot of CO_2 by combustion is equivalent to 160 foot-tons of energy. Therefore $17 \times 160 = 2,720$ foot-tons of energy are consumed in the production of the 17 cubic feet of CO_2 daily.

Again, if the average temperature of the air is taken as 50° F., the difference between the temperature of the human body (98·6° F.) and that of the air is 48·6° F. If, then, we consider the human body as absorbing and losing heat like water, the energy required to support a temperature of 98·6° F. in a man of 150 pounds weight is

$$\frac{150 \times 48{\cdot}6 \times 775}{2,240} = 2,522 \text{ foot-tons.}$$

(The number 775 is Joule's equivalent, *i.e.*, the number of foot-pounds of energy necessary to raise 1 pound of water 1° F.)

These two methods of estimating the amount of energy necessary to sustain human life are seen to produce similar results, viz., 2,720 foot-tons in one case, and 2,522 foot-tons in the other. The subsistence diet given in the table (p. 316) yields 2,344 foot-tons of theoretical energy. Playfair's subsistence diet (2·5 oz. protein, 1 oz. fat, 12 oz. carb.-hyd.), however, yields 2,430 foot-tons of theoretical energy, which approximates to the results of the two methods just described.

The resting output of energy may be taken to amount to 1 calorie per kgm. of body weight per hour.

The average diet for light work yields nearly 4,000 foot-tons of theoretical energy. If 300 foot-tons is taken as the energy consumed in actual physical labour, then $4,000 - 300 = 3,700$ foot-tons are consumed in supplying energy for the functions of the body in a state of physical activity. This would mean that during ordinary work the production of CO_2 is raised from 16 cubic feet to an average of 23 cubic feet in the 24 hours; or supposing the man works for 8 hours and rests for 16 hours, then the CO_2 produced in the 8 hours of work is 11·8 cubic feet (1·47 cubic feet per hour), and in the 16 hours of rest 11·2 cubic feet (0·7 cubic foot per hour). In the same way the diet for hard (laborious) work produces 4,930 foot-tons of energy; subtracting 500 for actual visible work, there is left 4,430 foot-

tons for the work of the body, equivalent to the production of 27·6 cubic feet of CO_2 in 24 hours, or 1·6 cubic feet per hour for 12 hours of work, and 0·7 per hour for 12 hours of rest.

The theoretical amounts of heat produced by the metabolism of various foods within the body have been calculated, and are stated in terms of calories—a calorie being the amount of heat required to raise a kilo (or 1 litre) of water 1° C., or, which is the same thing, 1 pound of water 4° F. In these calculations allowance is made for incompletely oxidized products.

The heat value, or amount of energy set free in combining with oxygen, of 1 gramme of each of the three chief nutritive constituents of food, when metabolized within the body, is as follows:—

Proteins	4·1 calories.
Carbo-hydrates	4·1 ,,
Fat	9·3 ,,

According to this, the diet for light work yields the following:—

	Oz. az	Grammes.	Calories.
Proteins	4·5	127	522
Fats	3·5	99	921
Carbo-hydrates	14·0	397	1,624
	22·0	623	3,067

The potential calorie values of articles of food are indicated in the table on p. 317-318, but, as previously stated, a certain portion of most foods is not absorbed during digestion, so that the actual food value is almost always less than the calorie equivalent. This loss may be stated at about 10 per cent. on the average.

The fuel value of Voit's standard diet for the average man doing moderate work is 3,050 calories. In America, the Atwater standard is the one usually accepted. This places the daily protein requirement at 125 grammes, with sufficient fat and carbo-hydrates to yield 3,500 calories.

The war ration of the British Army during the South African campaign contained protein 138 grammes, fat 105 grammes, carbo-hydrates 328 grammes, and had a value of about 3,900

calories. More recently the value of the diet for war was raised to between 4,500 and 5,000 calories. This addition suffices to keep the men in good condition, even in times of stress.

It is obvious that under conditions favouring rapid loss of heat a transformation of energy is involved in excess of the normal requirements of the work itself. In all calculations as to bodily needs, therefore, the influence of external conditions is a factor which cannot be ignored. According to Lefevre, every drop of 5° C. below 15° C. means an average increased energy output of 300 calories.

Professor Chittenden of Yale University, in his work on *Physiological Economy in Nutrition with Special Reference to the Minimal Protein Requirements of the Healthy Man*, maintains that health and vigour without loss of body weight, when equilibrium has once been established, can be maintained on a diet containing only from one-third to one-half of the protein stated to be necessary in the standard dietary scales which have received almost universal acceptance; and this without any increase, and even, in some cases, with a diminution in the non-nitrogenous elements of the diet. The experimental diets (Chittenden's) were "mixed," and not purely vegetarian, but meat was only sparingly taken.

Professor Chittenden's conclusions have been by no means universally accepted by physiologists and others interested in the construction of dietary scales, as they seem opposed to the general experience of civilized nations; and however interesting as indications of the adaptability of the human frame and functions to alterations in nutrition for comparatively short periods, the experiments were hardly of sufficiently long duration to warrant conclusions applicable to the life of a community for long periods. There are some also who think that a diet somewhat in excess of actual corporeal needs supplies a reserve of energy, which may be useful to prevent invasion of the system by the agents of infection, and to aid the restorative powers of the body in the case of actual sickness. It must be remembered, however, that if the protein is to be reduced to a minimum —*i.e.*, to the amount which will just replace the tissue waste— the protein must be of high biological value, such as is contained, for instance, in milk and meat. If, as is normally the case, we draw the greater supply of our protein from cereals, a larger

proportion will be necessary. Various foreign proteins from our foods have to be dissociated into their constituent amino-acids in digestion, and from the mixture of amino-acids thus formed the body has to pick out for purposes of repair just those acids in proper proportions which are necessary to recreate the proteins of the body. A considerable margin of protein is therefore necessary to provide for this transformation. The whole question of the adequacy of Chittenden's dietary scales under the many varying circumstances of mental and physical activity must, therefore, be still considered as *sub judice.*

When food is taken in large excess of the requirements of the system, a considerable portion remains undigested; fermentative and putrefactive changes are set up in the undigested mass as a result of the activity of the bacterial organisms always present in the intestinal canal, fœtid gases containing sulphur and carbon are formed, and dyspepsia and diarrhœa are provoked. Some of the products of putrefaction are absorbed into the blood, and cause fever, torpor, headache, and fœtid breath. Excess of fats and starches tends to produce acidity and flatulence; whilst taken habitually in excess they may cause excessive formation of fatty tissues and obesity. In cases of over-eating and faulty digestion, undigested muscular fibres, fat, and starch cells may be found by microscopical examination in the fæces to an unusual extent, and occasionally albumin and sugar will be found in the urine.

Deficiency in all the constituents of a diet tends to produce loss of weight, debility, prostration, and anæmia. If carried to the point of starvation, low fever and gastric disturbances are often excited, ending eventually in death. It appears, however, that some constitutions can withstand long periods of fasting (thirty to forty days), if plenty of water is taken, apparent health being maintained the whole time, although with gradually increasing emaciation and debility. The elimination of urea is always markedly diminished.

A slight reduction of food below the necessary requirement causes a large diminution in the working efficiency of the individual.

Malnutrition in childhood is generally due to parental ignorance or poverty; and well-planned meals are followed by a satisfactory rate of growth, increased physical and mental vigour. Speaking generally, in the diet of the poorer children carbo-

hydrates bulk too largely and proteids are deficient. Deficient nutriment in the years of physical and mental growth may be responsible for lasting effects upon the individual.

A due proportion of protein in the dietary of children must be maintained for proper health and growth, and where but little animal food can be afforded, it may be largely supplied in the form of oatmeal, peas, beans, and lentils, and cheese. A light nutritious diet in childhood may comprise the following selected articles: bread and milk; porridge with milk and sugar; wholemeal bread with butter or margarine, dripping, or bacon fat; toast and plain biscuits; eggs, fish (herrings); rabbit and chicken, peas, beans, and lentils, with fat or oil; bread and butter pudding; rice, suet, and batter puddings with treacle or honey; cheese (very good for older children); green vegetables, dates, figs, nuts, apples, and stewed fruit. Cocoa with milk and sugar, and chocolate, are nourishing beverages.

The considerations which will influence the selection of a diet must not be limited to the subject of calories. They may be briefly summarized as follows: (1) Age. It is generally held that a child of ten requires slightly over half as much, and a child of fourteen quite as much, as a woman; for growing children have not only to make good the daily loss of much energy, but also to provide the food needs for growth. An average diet for a child between eight and fourteen years of age should contain about 6 ounces of meat, 14 ounces of bread, 6 ounces of potatoes, 9 ounces of milk, and small quantities of butter, fresh vegetables, tea or coffee. More especially in childhood must the vitamine need be kept in view. A generous diet for a working man would contain 9 ounces of meat, 18 ounces of bread, 16 ounces of potatoes, 16 ounces of milk, 2 ounces of butter or dripping, and 3 ounces of oatmeal. Old people should be given somewhat less proteid (about 15 per cent. less) and carbo-hydrates, and slightly more fat, than those in middle life. (2) Sex. Women require on an average one-eighth less food than men. (3) Selection of food. In making the selection, the local market will have to be studied; and it is essential to furnish a sufficient variety of palatable food. The digestibility of various articles of foods must also be taken into account. On an average, about 5 to 10 per cent. of all the common food-stuffs is indigestible. (4) The appearance, the flavour, and the suitable combination of foods play a part in the physiology of nutrition. (5) As soon

as the demands of the body become excessive (over 4,000 calories) the proportion of the fat in the diet should be increased. The Inter-Allied Scientific Food Commission (1917) concluded that 75 grammes of fat per diem is the minimum desirable ration for the average man utilizing 3,000 calories—or, allowing for waste, 3,300 calories in food as purchased. In distributing meat rations it must be borne in mind that 20 per cent. of the gross weight must be deducted for bone. (6) Cost. The dietetic value of food materials by no means corresponds with their relative cost; dried peas, haricot beans, and lentils contain much flesh-forming substances, and are very much cheaper than meat. (7) As to meals, it is the usual practice to provide four meals daily: breakfast, dinner, tea, and supper—at intervals of about four hours, although three meals a day are sufficient.

The following dietetic facts should be more generally known and applied:—With reference to vegetable foods: Wholemeal bread is more nourishing than white, and therefore it is more economical. Oatmeal is a very nutritious food, but it requires thorough boiling to make it digestible. Potatoes give best value when cooked in their skins or steamed. Onions, beetroot, and carrot are more nutritious than cabbages; but all vegetables and fruit are valuable in a diet. Bananas, raisins, and dried currants are cheap and nourishing. Sugar and treacle are useful foods, but jam is of less value. With reference to animal foods: herrings, bloaters, and kippers are most nourishing. Frozen meat and the cheaper cuts of fresh meat contain as much nourishment as the best cuts; excellent stews may be made from them with cheap vegetables. Fresh foods are better than canned foods. Dripping and margarine contain as much energy value as the best butter, and dripping is well worth buying, being a valuable food for children. Suet puddings should be given to children who dislike fat meat. Cheese is one of the cheapest and best of foods, but some children cannot digest it.

The Hand-Feeding of Infants.

Until the child is at least seven months old nothing but milk should be given, for it is unable to digest starch and other foods. The following instructions may be advantageously followed, at the earlier ages in cases where the mother is unable to suckle her infant, and at the later ages in all cases:—

Age of Child.	Milk (Tablespoons).	Water or Barley Water (Tablespoons).	Total Amount to be given at each Meal (Tablespoons)	How often to Feed.
During 1st fortnight	1	2	3	Every 2 hours
,, 2nd ,,	$1\frac{1}{2}$	2	$3\frac{1}{2}$	,, 3 ,,
,, 2nd month	2	2	4	,, 3 ,,
,, 3rd ,,	4	3	7	,, 3 ,,
,, 4th ,,	5	3	8	,, $3\frac{1}{2}$,,
,, 5th ,,	6	3	9	,, $3\frac{1}{2}$,,
,, 6th ,,	7	3	10	,, 4 ,,
,, 7th ,,	8	2	10	,, 4 ,,
,, 8th ,,	10	1	11	,, 4 ,,
,, 9th ,,	12	—	12	,, 4 ,,

At the commencement of the sixth month $\frac{1}{4}$ to $\frac{1}{2}$ teaspoonful of white sugar and $\frac{1}{2}$ teaspoonful of cream or olive oil should be added to each feed.

From the age of seven months to twelve months, three of the meals may also each contain about a teaspoonful or more of baked flour or arrowroot, or of some infant's food, well boiled and stirred up with the milk.

From the age of twelve months to eighteen months porridge, bread and milk, bread and gravy, bread and butter, and a lightly boiled egg occasionally, may be given with advantage, or in place of some of the milk, as time goes on.

Any advice card that is circulated after the receipt of the notification of a birth should strongly press for breast-feeding, and purposely omit any advice as to artificial feeding, in order to influence the mother or any other person in attendance to persevere with breast-feeding, when possible, until the Health Visitor comes upon the scene—which is generally ten days after the birth of the child—by which time the doctor or midwife has generally ceased attendance.

When nine or ten months old, the child should, as a rule, be gradually weaned, but it is well not to commence in very hot weather, owing to the risk of summer diarrhœa.

Feeding bottles should be boat-shaped, preferably with an opening at each end. They should be fitted with a short rubber teat, capable of being easily turned inside out for cleaning. The long feeding tube usually found in use very quickly becomes foul, and should not be employed. Any milk left in a feeding bottle after a meal should be at once emptied away. Two bottles should be used alternately, each bottle being boiled and rinsed immediately after use, and placed neck downwards to drain in a cool, clean place, so that no dust may get into it. Condensed milk is never so good for infants as fresh milk; if used at all, it should be condensed "whole" milk. Condensed milk should never be given to an infant from a tin which has the words "hand skimmed" or "machine skimmed" upon the label, for such milk has been robbed of a very important nutriment, and a child cannot thrive on it, however much is taken.

It is harmful to give children tea, beer, spirits, or cheese, for they interfere with the power of digestion; and teething powders or soothing syrups are dangerous because they often contain opium.

When an infant is fretful or suffering from indigestion or diarrhœa, it will often be found that it is having too much or too strong food, and is fed too frequently. By diminishing its diet or diluting the milk with a little extra water, and carefully attending to the proper feeding times, the child will often get well. If, in spite of every care, it continues so to suffer, proper medical advice should always be sought.

Relatively too much starchy food along with too little fat is ascribed as a cause of rickets in young children.

Proprietary Foods.—These are dried preparations of various kinds. The ones most suited for infant feeding should approximate to the composition of dried human milk, namely, proteids 16 per cent., fat 32 per cent., sugar 49 per cent., salts 3 per cent. Those prepared from whole cow's milk contain no unaltered starch, all the carbo-hydrate being in the form of sugar, or at least freely soluble. They only require the addition of boiled water to make them ready for use. These foods may sometimes be used advantageously, as in times of epidemic diarrhœa, for infants. A small quantity of fresh fruit juice should be given, as they lack the antiscorbutic vitamine. Another class of prepared foods are the farinaceous substances obtained from cereals—usually wheat flour—the starch in these foods having been wholly or partly transformed by enzyme action and heat into soluble substances—*e.g.*, malt, sugar, and dextrin. These only require the addition of fresh milk to make them ready for use. Those foods in which the starch is not converted, or is only converted, and that not completely, during the process of preparing the food for the infant, should not be used for infants under seven months of age. Even although prepared with fresh milk these farinaceous foods are relatively deficient in protein and fat, and are unsuitable for the continuous feeding of infants under seven months.

Dr. F. J. H. Coutts, as the result of an investigation into the use of proprietary foods for infant feeding for the Local Government Board (1914), recommends that foods containing unchanged starch, or starch altered only by heating, should not be given to infants under seven months except under medical supervision. Similar precautions should be observed with regard to the use of barley water as an adjunct to the infant food.

Some infants may in time accommodate themselves to an

excess of starchy matters in their food, activating enzymes being in time produced which increase the naturally weak amylolytic action of the pancreatic juice. The consequent hurrying on of a natural process before its time, *i.e.*, the formation of starch-splitting enzymes in excess of the amount normal to the age of the infant, is probably prejudicial to most infants, as it leads to an expenditure of vital energy in an unnatural manner, which the infant cannot afford without suffering in some other respect.

Meat.

Meat contains a large quantity of nitrogenous material, some fat, and salts—chiefly the chlorides and phosphates of potash. It is rapidly digested and easily assimilated, and hastens tissue metamorphosis.

The proteins form about 20 per cent. of raw meat (beef), of which about 15·5 parts are digestible albumins, peptones, and extractives, the remaining 4·5 parts being indigestible.

Bones contain a large amount of nourishing material, viz., proteins (gelatine), 24 per cent.; fat, 11 per cent.; ash or mineral salts, 48 per cent. A most nourishing soup can be prepared by boiling bones.

In inspecting meat, the muscles should be found firm and elastic, of a deep red colour (neither purple nor pale, flabby nor sodden), and marbled with fat, in well-conditioned animals. There should be no excess of moisture, no pus or fluids in the intermuscular cellular tissue, and no lividity on cutting the muscle across. The flesh must be quite free from deposits (tumours). The odour should be fresh and not unpleasant, without a suspicion of putridity or smell of physic. Meat which has commenced to putrefy is pale and soft; the reaction of the juices is no longer acid; and later the meat becomes greenish. If the odour of putrefaction is not otherwise apparent, a knife or a new wooden skewer should be thrust into the meat and then held to the nose; or a little of the meat may be chopped up and soaked in hot water, when the steam arising may be found offensive. The fat should be firm and of a pale yellow colour, and free from hæmorrhagic points. The lymphatic glands afford an excellent clue to the existence of disease if they are enlarged, congested, or show deposits. In bovines the chief lymphatic glands are to be looked for immediately in front of the spinal column (cervical,

thoracic, and lumbar glands), between the two lungs (mediastinal), on both sides of the trachea or wind-pipe near to its bifurcation (bronchial), and in the inguinal region. In health these lymphatic glands are about the size of a pea. Any lymphatic glands attached should be firm, slightly moist, and of a pale greyish-yellow colour on section; and the marrow of the bones should be light red. The lungs should be examined for inflammation or abscesses, tuberculosis, or actinomycosis; the liver for distoma or liver-fluke, tuberculosis, or hydatid tumours; and the spleen for enlargement or nodules.

The Important Parasites of Flesh.

CYSTICERCI.—The cysticercus, or "bladder-worm," causes the condition known as "measles" in the pig, ox, and sheep. When measly flesh is consumed by man, the "bladder-worm" undergoes a series of changes which terminate in its conversion into a tapeworm. In the flesh of the pig, and much more rarely in that of dogs, monkeys, or man, a number of small oval or round cysts are seen, occupying a position between the muscle-fibres, and commonly varying in size from a pea to a cherry—though they have been found as small as $\frac{1}{25}$ inch, and as large as $\frac{3}{4}$ inch in diameter. These cysts are the *Cysticerci cellulosæ*—the bladder-worms which form a stage in the development of *Tænia solium*. The cysticerci are surrounded by a pale milky-looking fluid, and the cyst wall shows a white spot (generally central) upon its surface. The affected flesh is pale, soft, unduly moist, and flabby, and it has a smooth slippery feel. Sometimes there is some degree of calcification of the capsule, the result being that, when sections are cut, a grating sensation is experienced.

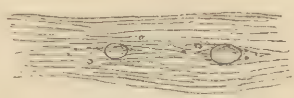


FIG. 55.—"MEASLY" PORK, SHOWING (DIAGRAMMATICALLY) ITS APPEARANCE TO THE NAKED EYE.

FIG. 56.—HEAD OF TÆNIA SOLIUM. (Obj. $\frac{1}{2}$ inch.)

The bladders should be incised with a sharp knife, and the worm examined by a powerful hand lens, when at one extremity will be found the blunt square head provided with a sucker at each "angle," and a fringe of hooklets placed more centrally.

These hooklets are very characteristic, and must always be found before a definite diagnosis is ventured on.

Those cysts that are dried up and indistinct can be made visible by soaking in weak acetic acid. Ostertag attaches great diagnostic importance to the rounded or oval calcareous corpuscles, which are so generally embedded in the tissue of the head, but which disappear on the addition of acetic acid.

Young pigs are more especially liable to be attacked; and during life the earliest evidence of the parasites is afforded by the presence of one or more small cysts in the conjunctiva, or in the loose tissue of the frænum linguæ. After death the liver and the muscles of the shoulders, intercostals, and loins are seen to be chiefly affected.

FIG. 57.—HEAD OF TÆNIA MEDIOCANELLATA. (Obj. ½ inch.)

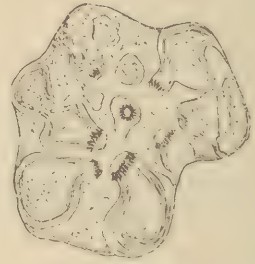


FIG. 58.—BROOD CAPSULE OF AN ECHINOCOCCUS.

The Cysticercus of the Ox.—Cysticercus bovis, or " beef-measles," which chiefly affects the calf, possesses a flat head armed with no hooklets, but simply with suckers, around which there is frequently a considerable deposit of pigment; and on the surface of the head there is a pit-like depression (" frontal suction cup "). It develops in man into the adult tapeworm called *Tænia mediocanellata*, which is longer than *T. solium*, and appears to be more prevalent in this country.

Bothriocephalus latus, a tapeworm which is almost limited to certain parts of the Continent of Europe, is even larger than *T. mediocanellata*. It has a club-shaped head, not armed with hooklets, but possessing two deeply grooved longitudinal suckers, one on each side.

Tænia echinococcus is the small tapeworm, of three or four segments, with a head provided with suckers and hooklets, which is commonly found in the dog. The encysted form (" hydatids ")

is generally found in the lungs and liver of oxen, sheep, and swine, and in man when, as more particularly in Iceland, he lives in close association with dogs. The hydatids consist of thin pale vesicles floating in a clear liquid, the whole being encysted in a tough capsule. The inner lining of the capsule consists of ciliated epithelium; and from the inside of the cyst wall there generally arise many so-called "brood capsules" (fig. 58).

The condition is diagnosed with certainty by the microscope either by the discovery of the characteristic heads or of detached hooklets in the clear liquid of the cyst. Valuable corroborative evidence is furnished by the fact that the liquid is quite free from albumin, and, in consequence, does not coagulate on boiling.

FIG. 59.—TRICHINA SPIRALIS ENCYSTED IN MUSCLE. (× about 40 diameters.)

TRICHINA SPIRALIS.—This parasite has been found in the flesh of many different animals (pigs, pigeons, eels, etc.), but most commonly, by far, in that of pigs. Oxen and sheep do not suffer from attack by these nematodes.

The shape of the minute worms is nearly that of a typical nematode, *i.e.*, a slender rounded body tapering gradually at either end. The extremity which constitutes the head proceeds to a slender long point having a small central orifice—the mouth; the other extremity, the tail, ends more bluntly. The worms possess a distinct alimentary canal, and even rudimentary sexual organs are present. In the female a uterus is discernible, which will frequently be seen to be full of minute free embryos curved upon themselves; these latter have been observed to become extruded from the vagina, and subsequently to move sluggishly about the field of the microscope.

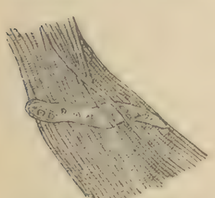


FIG. 60.—ONE OF RAINEY'S CAPSULES. (× 285.)

The male worm is much smaller than the female, and is only about $\frac{1}{16}$ inch long when mature; the female reaches to $\frac{1}{8}$ inch. The long slender head and blunt tail are two characteristics which serve to distinguish these worms from parasites which otherwise resemble them, such as *Dracunculus* and *Filaria sanguinis hominis*.

The small worms are mostly coiled up in cysts, so disposed that their longest diameter is in line with the muscular fibres; and a drop of acid will stimulate them to transient movements if they are alive. These cysts lie between the muscle fibrillæ, and their walls are sometimes partially or completely calcified, so as to give a grating sensation when the finger is passed over a section of the flesh. This calcareous deposit serves to shield the parasites from the destructive consequences of salting, and to a slight extent also from heat when the flesh is being cooked. There may be from one to three trichinæ in a cyst. Frequently 25 per cent. of these parasites are encysted in the diaphragm of the host; and therefore, when possible, a piece of this muscle should be procured. The back muscles, on the other hand, are the least attacked.

Either a section may be made of the muscle, or it may be teased out with needles; and preferably, in the case of a long muscle, a point near its insertion should be selected for teasing—since this is a favourite site for encystment. The affected muscle is seen to be pale and œdematous; and, if the worms are encapsuled, small, rounded (or, more truly, lemon-shaped), whitish specks, averaging about the size of a very small pin's head, are visible to the naked eye. These can be made very distinct by means of a hand lens; but a low power of the microscope should be employed in every case. The most characteristic appearance will be got by making a thin longitudinal section of the affected muscle, and immersing this in potassic hydrate solution of medium strength—which serves to make the muscle fibres transparent, and leaves the worm exposed in its coiled condition within the capsule. The soaking should not be prolonged beyond a minute or two, or the worm itself will also be cleared up. Glycerine is a good mounting medium when a permanent specimen is desired. Sometimes, owing to a considerable calcareous deposit in and around the walls of the capsule, a view of the worm is obscured; in these cases a drop of dilute hydrochloric acid, run under the cover-glass, will dissolve this deposit; or if, as is sometimes the case, one or more oil globules partially obscure the worm, a drop of ether, applied in a similar manner to the acid, will clear away the fat. There are generally oil globules at the poles of the capsule.

The parts of the body which are most likely to be affected will easily be remembered if it be borne in mind that the worms

migrate to their settlements from the gastro-intestinal tract, and chiefly from the commencement of the small intestine. The diaphragm, the liver, the intercostal and abdominal muscles, are necessarily the first encountered, and therefore suffer most; but in later stages of the infection there is hardly a muscle which may not be affected. It is also a common practice to make an effort to diagnose the presence of the parasites in the living animal, by examining the eyes and the under surface of the tongue, both of which will frequently show the small pinhead deposits.

The dangerous and often fatal disorder created by these worms, as they traverse the gastro-intestinal walls and travel to their encystment in the various organs of the body, is most prevalent in those countries where the uncooked or imperfectly cooked flesh of the pig is consumed, as in the form of sausages, ham, etc.

Hot smoking and efficient cooking destroy these parasites, but in the latter case the meat must be "done through"—*i.e.*, thoroughly cooked through the centre—or some of the parasites, especially when shielded by calcareous walls, may escape the temperature necessary to destroy them—that of 150° F.

There are certain small semi-transparent bodies, called "psorospermia," or "Rainey's capsules," which somewhat closely resemble trichinæ, presenting as they do small dark oval or elliptical bodies, of greater lengths, however, than encysted trichinæ. They are made up of a thick membrane, formed by small hairlike fibres arranged in lines, which encloses small oval or kidney-shaped granular cells, closely adherent together; and the whole lies embedded in the muscle substance itself, *i.e.*, the sarcolemma. They are extremely common, and may exist in the flesh of most of the animals used for human consumption, and apparently when eaten they do no harm.

Several more obscure bodies, the nature and significance of which we are still more ignorant of, may exist in flesh, such as bodies somewhat resembling pus cells, and others forming minute concretions or tiny hard nodules. Interesting as these are pathologically, they are rare, and when present even in considerable numbers do not appear to affect the wholesomeness of the meat to any degree.

Actinomycosis.—The "ray-fungus" (actinomycosis), one of the "fission fungi," is now becoming recognized as a parasite of commoner occurrence in the ox than was once suspected. The

difficulties which stood in the way of an earlier appreciation of this fact arose from the circumstance that both the ante- and post-mortem appearances of the disease closely simulate those of tuberculosis.

It has not yet been proved that the disease can be communicated by the cooked flesh of animals (bovines) suffering from an attack, for the vitality of the fungus when exposed to heat is very slight. The subject is of such interest and importance, however, that a few additional facts are appended.

FIG. 61.—DISTOMA HEPATICUM. (Natural size.)

The parasites chiefly affect the tongue, the jaws (especially the lower one), and the lungs, where they may be detected, by the naked eye, as small dirty white specks commonly about the size of a very small pea, but varying from the tiniest speck up to $\frac{1}{3}$ inch in diameter. The parasites assume, when encysted, a peculiar symmetrical appearance, due to the fact that they consist of small linear elements, thicker at one extremity than at the other, and so arranged that their smaller extremities are all directed towards a central point; the stellate or rayed appearance thus created is sometimes remarkably regular and uniform. The tongue when affected is hard and swollen, and presents the flattened nodules chiefly upon its dorsal aspect. There are many species of actinomycetes recoverable from soil, but *Actinomyces bovis* has not yet been found outside the animal body.

DISTOMA HEPATICUM.—To examine for these parasitic trematodes the liver should be taken, and the bile ducts carefully exposed. The parasites will be found as small organisms of a pale brown colour, in shape like little soles, and provided at their broad extremity with a sucker for attachment to the walls of the bile ducts. Their surfaces are beset with many little warty points, and they average in size from 1 to $1\frac{1}{2}$ inches in length, and about $\frac{1}{2}$ inch in width. They generally attach themselves to the biliary ducts, but they may be found also in the parenchyma of the liver.

The Life-histories of the Animal Parasites of Man.

Tænia solium.—Portions of the ripe proglottides of the fully matured tapeworm are swallowed by pigs, or more rarely by dogs, monkeys, or man. Very commonly the ova they contain escape

and become scattered—some into water, others upon grass or vegetables, where they may certainly survive for some days. If the eggs are ingested, on reaching the stomach the shell becomes dissolved by the gastric juice, and the embryo (a globular body armed with three pairs of hooklets) bores its way through the stomach or intestinal walls, and finally comes to rest in some part of the body. It then grows in size, loses its six hooklets, and after a time develops a head provided with four suckers, and armed with a circle of minute hooklets (" bladder-worm," or *Cysticercus cellulosæ*). The head grows out from the inside of the bladder, to the wall of which it is attached by a constricted part known as the neck or pedicle. The parasite may remain in this condition for long periods, or may shrivel up and die, for it is incapable of further development until it is ingested by a carnivorous animal. When this occurs, on reaching the alimentary canal, it projects its head and neck (by invagination), the bladder part is dissolved by the gastric juice, and very shortly transverse lines appear on the neck, which increase in size and so separate from each other, until after a few weeks a jointed adult tapeworm results, with proglottides charged with ova ready to commence a fresh cycle.

The life-histories of *Tænia mediocanellata* and *Bothriocephalus latus* are similar to that of *T. solium ;* but the bladder-worm of the *Bothriocephalus latus* is supposed to inhabit some species of fish (perch, pike, and salmon trout ?), or possibly a fresh-water mollusc.

Distoma hepaticum.—The ova develop, in water, into ciliated embryos, and these undergo in small water snails (*Limnæus truncatulus*) a further development into larvæ. These larvæ ultimately become little organisms resembling tadpoles (*cercaria*), which either remain encysted in water snails, or leave them and become attached to grass. They are generally taken up by a grazing sheep, but very rarely man also becomes a host.

Tænia echinococcus.—Of the three or four segments of this tapeworm the last one only contains sexual organs. The ova are discharged with the fæces (commonly of dogs), and they probably infect cattle, swine, and man through the medium of water or raw vegetables. On entering the stomach the gastric juice dissolves the shells of the ova, and liberates the embryos, which possess six hooklets in two rows; by means of these hook-

lets the embryo bores its way through the walls of the intestine and develops, chiefly within the liver, into so-called "hydatid cysts"; *i.e.*, the hooklets are lost, and the formerly solid embryo swells out into a vesicle. Generally a number of protrusions ("daughter cysts") grow from the interior of the vesicle, which itself forms a cyst ("mother cyst"). To the mother cyst the daughter cysts are attached by a pedicle, which ultimately becomes detached. Each "daughter cyst" may develop "grand-daughter cysts," and thus the original echinococcus may become full of small cysts of varying sizes ("pill-box hydatids"). Finally the little buds develop into "brood capsules," *i.e.*, thin walled sacs which remain attached by a pedicle, each sac developing a number of heads, with four suckers and a row of hooklets apiece.

Thus the encysted form of these parasites possesses the distinguishing feature of being able to give rise to a large number of scolices, most of which are capable of developing into the adult worm when they enter another host.

Rarely the hydatid throws out protrusions externally.

Ascaris lumbricoides (the round-worm).—The ova of the females are discharged with the fæces of the host, and then they become capable of furnishing embryos, a power not hitherto possessed. The embryos probably have an independent existence (possibly in water or in some intermediate host—such as worms or insects) before again entering the human body, and completing their development. The parasites inhabit the small intestine, are of a brownish-yellow colour, and are most commonly met with in people who live amid dirty surroundings.

Oxyuris vermicularis.—These fine, white, thread-like parasites occupy the large intestine. The ova, unlike those of *A. lumbricoides*, contain embryos prior to their discharge; but probably these are incapable of further development until they have passed with the fæces, when they may reinfect the same individual or others occupying the same bed, etc., or may pass into water, or become deposited upon vegetables and fruit, and thus again become ingested.

The life-histories of *Trichocephalus dispar* (whip-worm) and *Sclerostomum duodenale* (common in Egypt and Brazil) have not yet been definitely ascertained. It is not yet certain by what vehicle the ova of the females (which develop in man) infect their host, or whether in either case there is an intermediary stage of development of the parasite.

Bilharzia hæmatobia.—The male is a white flattened worm, ½ inch in length; posteriorly the sides of the parasite curve towards each other, and meet to form a channel, in which the long slender female (¾ inch in length) lies during fecundation. The ova possesses a beak, which generally projects from one end, but sometimes laterally. These ova may be hatched before the parasite leaves the tissues of the original host, but the embryos are not born until afterwards. If the ova find their way into water, their walls swell up and rupture, and the minute embryos escape, armed with cilia, which serve to project them through the water. Probably the embryo becomes attached to some fresh-water mollusc (or possibly some fish), and, developing into a cercaria form, infects man through the skin or mucous membrane of the mouth and throat, and then completes its cycle of development.

Trichina spiralis.—When trichinous meat is consumed, the trichina embryos (averaging a little over 0·1 mm. in length), which resemble small filariæ, bore their way through the intestines and reach the tissues. They always become encysted in muscle fibres, where they increase in size (up to 0·6 to 1 mm. in length), and acquire an alimentary canal and sexual organs. The encysted worms remain quiescent for long periods, and may ultimately die; but if trichinous flesh is eaten they give origin, through their embryos, to a fresh cycle of existence.

Horseflesh.

By the Horseflesh Act (1889) powers are given to the Officers of the Local Sanitary Authority, for the inspection, examination, and seizure of horseflesh sold for human food, from any shop or stall not conspicuously labelled "Horseflesh is sold here." It becomes necessary, therefore, in order to check fraud, to be familiar with the chief differences which exist between the meat of the ox and that of the horse. In horseflesh the meat is of a darker red, and sometimes brownish in hue; it is coarser—the muscular fasciculi being broader—than in oxflesh; the odour of the fresh meat is different, and after the lapse of a day or two, as the flesh dries, it develops a peculiar faint odour and imparts a soapy feeling to the fingers. The fat is more yellow and soft, and possesses a sickly taste, and, in consequence, it is sometimes removed and replaced by ox fat, which is skewered on the meat. If the bones have not been removed, they will afford an additional

clue, inasmuch as they are larger, and their extremities (tuberosities, etc., for the attachment of muscles and ligaments) are larger and more marked, these signs being additional to some anatomical differences in the construction of the horse's skeleton. For instance, the horse has eighteen ribs, fixed by long unions with the cartilages, and a keel-shaped sternum; whereas the ox has thirteen ribs, jointed to the cartilages, and a flat and broad sternum. For these reasons horseflesh is usually boned before it is offered for sale as beef.

The tongue, kidney, and the liver of the horse, together with some other organs, are also occasionally placed on sale as the corresponding organs of the ox. The tongue of the horse is, however, broad and round at its free end, instead of pointed, as in the ox; and if the hyoid bone is attached, it is found to be made up of five parts, whereas that of the ox consists of nine. Moreover, the base of the horse's tongue is smooth on its dorsal aspect, whereas that of the ox is rough from very prominent papillæ. The epiglottis is smaller and more pointed in the horse. The liver, whether of the ox or sheep, consists of one very large lobe and another relatively small one; in the horse there are three large and distinct lobes, and a fourth relatively smaller one, and there is no gall bladder. The kidney of the horse is more heart-shaped, and cannot be mistaken for the long lobulated kidney of the ox.

The heart of the horse differs from that of the ox in being less conical, darker, softer, and with less fat at its base; and without the bone that is found in the heart of the ox.

Cooking of Meat.

The *cooking* of meat preserves it from putrefactive changes by heat sterilization, may somewhat increase its digestibility, and produces that palatability which a civilized taste demands.

By cooking, the connective tissue binding together the muscular fasciculi tends to become disintegrated. The connective tissue is changed into more or less soluble gelatin, the meat is made tender and easier to chew, and the proteins and fats are more perfectly exposed to the solvent action of the digestive juices. The flavour induced by cooking stimulates the secretion of digestive juices.

In all cooking processes meat loses weight, usually from 20 to 30 per cent. In *boiling* a joint, the meat should be plunged

into boiling water for five minutes to coagulate the outside albumin and retain the salts, extractives, and soluble substances in the interior. The remainder of the boiling should be conducted at a temperature below 170° F.—which is the temperature at which most of the albuminoids coagulate—in order that the meat may not become tough, dry, and indigestible. On the other hand, in making broth the meat should be cut into small pieces, and placed in cold water, which is gradually warmed to 150° F.; in this way the salts and extractive matters pass out of the meat into the broth, together with a certain proportion of the more soluble proteins.

In *baking* and *roasting*, the joint of meat should first be subjected to an intense heat, in order to coagulate the outside albumin and retain the soluble juices. After a few minutes the temperature should be lowered and the roasting or baking completed at 180° F. to 200° F. Aromatic products are formed in roasting and baking which are volatilized; some of the fat is melted and flows out of the joint together with gelatin and extractives to form the gravy.

The gas cooking ovens, which have now come so largely into use, present several advantages over kitchen ranges heated by coal. They are very cleanly; the temperature of the oven can be adjusted with great nicety by regulating the consumption of gas; there is the convenience of the oven being ready for use in a few minutes after the gas is lighted; and as soon as the cooking is finished the gas can be turned out. It is very difficult to distinguish between a joint of meat baked in a gas oven and one roasted before an open fire, if the gas oven is properly ventilated and a flue is provided to carry off the products of combustion. If the ventilation is insufficient either in a gas oven or ordinary close range oven, the meat becomes sodden in its own vapours, and in the case of the gas oven also with the gas products, which give it a disagreeable taste and odour. Gas cooking stoves should be provided with Bunsen burners, arranged round the side of the oven at the bottom; and the oven walls should be double, the space between the plates being well packed with slag wool to prevent loss of heat. No soot is formed in gas cooking, and there are no dust, ashes, and dirt, as in a coal cooking range.

Meat can be *preserved* by drying in strips in the sun, called jerking; by salting; by canning, *i.e.*, by heating, and thereby sterilizing the meat in tins, which are hermetically sealed by

solder at a high temperature; and by refrigeration in the raw state—a process now very largely used, the refrigeration chambers on board ship permitting of the importation into this country of meat from South America and the Australian colonies. The last process is by far the best, as the freshness and nutritive value of the meat remain unaltered. It is not easy to distinguish a New Zealand joint of mutton from the home product—if it is properly thawed before being cooked. The low temperature of the ice house (not less than 6° F. below freezing point) does not destroy all bacteria, but prevents the development of the organisms of putrefaction. The preservation, for many ages, of the Siberian mammoth in its icy casing is a notable example of the antiseptic properties of great cold.

Frozen meat can generally be distinguished by the uniform and darker colour of the meat, even the fat being stained by the exuded juices from the lean parts. It is also softer to the touch. The external surface of the meat is duller and browner than that of fresh meat, and the joints are not usually so well dressed as in the case of home killed meat. American killed carcases can generally be told by the bruises about the legs, by which the animals are hoisted prior to slaughter.

Effects of Diseased or Unsound Meat.

In a Report to the Local Government Board on Bacterial Food Poisoning and Food Infections (1913), Dr. W. G. Savage is of opinion that the great majority of outbreaks of " meat poisoning " are due to infection of the food with bacilli of the Gaertner group, the food being contaminated in some cases because it is derived from an animal suffering from a general or local disease caused by one or other member of the true Gaertner group, and in others because, subsequent to slaughter, Gaertner group bacilli from outside sources have gained access to it. The diseases of animals used for food, caused by Gaertner infections, are swine fever (*B. suipestifer*), and certain septicæmic and dysenteric diseases of calves and cattle in which *B. enteritidis* is the predominant organism found. These diseases are not very uncommon in animals used for food, and their occurrence is sufficient to explain those outbreaks of food poisoning in man in which definite disease of the animal supplying the meat has been ascertained to have existed. In regard to the outbreaks in which the Gaertner group bacilli have gained access to the meat

or food from outside sources, the infection may have been due to contamination of the food by carriers (animals or man), or to contamination by rats and mice suffering from *typhus murium*, a disease in which the bacillus belongs to the Gaertner group, and was first isolated by Danysz.

The virulence of the infecting bacillus, as well as the number present, is of much importance as regards the initiation of infection in man. Meat poisoning outbreaks are far more prevalent in the summer months, the rate of multiplication of these bacilli being greatly favoured by a high temperature, and possibly also their virulence and pathogenicity to man.

It was at one time thought that putrefactive changes in meat were sufficient to account for the illness associated with outbreaks of food poisoning, but it is now generally held that the microbes concerned with putrefaction (*Proteus vulgaris*, *B. proteus*), etc., and the products of putrefaction are not really the causes apart from the presence of Gaertner group bacilli. What was formerly known as ptomaine poisoning is now recognized as being due to infection with these bacilli, the bacilli themselves producing toxins which are the cause of illness. There is no evidence, either, connecting *B. coli* and its allies with outbreaks of food poisoning.

The incubation period, or the period between the consumption of the infected food and the onset of symptoms, varies greatly, being in some cases as short as half an hour, and in others thirty hours or longer. The most usual period is six to twelve hours. The period varies in different outbreaks, and even in the same outbreak widely different periods are recorded. If the toxins are preformed by Gaertner bacilli in the food, the incubation is a short one, but if the toxins are formed in the body after the ingestion of the food, the symptoms of illness are longer in manifesting themselves. In a majority of outbreaks, and in most individual cases, the illness is partly due to toxins preformed in the food, and partly to toxins elaborated by bacilli in the body after consuming the food.

The onset of symptoms is usually sudden—marked gastro-intestinal irritation frequently accompanied or followed by great nervous prostration. There is vomiting in many cases, and in all cases intense diarrhœa, and severe abdominal pain. Cramps, rigors, and collapse occur in bad cases. Herpes and erythematous rashes are not uncommon. In many outbreaks the case mortality

is low (1 to 4 per cent.), but occasionally much higher. The changes found on post-mortem examination are often slight compared with the severity of the symptoms. The mucous membrane of the stomach and intestines shows minute hæmorrhages, and is swollen and congested, but there are few other marked changes.

As a general rule, in the outbreaks studied, the food affected was not noticeably altered in appearance, taste, or smell. In some instances changes have been noted, but not amounting to marked putrefaction. Those who eat the food on the day it was prepared are often less affected than those who consume it later, pointing to the element of time being necessary for the production of the toxins in the food.

Sausage poisoning, or "botulism," is now a very rare occurrence in this country. The sausage becomes contaminated with *B. botulinus*, which is probably derived from pigs or pig excreta. This bacillus is a large spore-bearing anaerobic organism, which produces powerful toxins. It is easily destroyed by heat, light, and air, and the spores are not highly resistant, but there is evidence that they are not completely destroyed by cooking. The symptoms, which are chiefly those of intense nervous prostration, come on from twenty-four to thirty-six hours after eating the contaminated sausages. This form of poisoning has also been conveyed by ham, blood puddings, salted fish, and preserved beans and fruit. The case mortality is 25 to 30 per cent.

The diagnosis of the various forms of food poisoning is based upon the isolation of the bacilli from the excreta, or, after death, from the spleen, liver, or intestines, the feeding of mice or guinea-pigs upon cultures prepared from the isolated bacilli, and the agglutination test with the patient's serum upon known cultures of the organisms isolated.

Various suggestions have been made with the object of further protecting the public against outbreaks of meat poisoning. Doubtless the absence of public abattoirs and the unsuitable provisions for storing food in homes and in shops are mainly responsible for such occurrences. We are not in a position to lay down bacterial standards of cleanliness; but there is much to be said in favour of the registration with the Sanitary Authority of all places where food is prepared for sale; the bringing of such places under by-laws requiring cleanly premises, cleanly

practices, and healthy workers; and the notification of cases of food poisoning by medical men.

In investigating a case of food poisoning, it is best to enter on a paper every article that has been consumed in the affected household or households, and then by a process of exclusion to determine the article or articles that have been eaten in common by the sufferers. The suspected article must then be traced and secured, and the correctness of the conclusion confirmed by feeding experiments on one of the lower animals and a bacteriological investigation.

There are certain diseases of animals which are known to be, or believed, on good grounds, to be transmissible to man. These are anthrax and malignant pustule, tubercle, foot and mouth disease, rabies, glanders and farcy in horses, *Cysticercus cellulosæ* and *bovis* in the pig and ox, respectively, and *Trichina spiralis* in the pig. With the exception of cysticercus and trichina these diseases are far more frequently transmitted to man by other means than by the consumption of diseased flesh. But it must be remembered that such transmission is possible in respect of several diseases, and would probably be much more frequent than it is, were it not for the precautions taken to prevent the sale of unsound meat, and for the safeguard of cooking. In some diseases it is generally held to be sufficient to condemn the affected parts, if the rest of the carcase appears healthy.

Tuberculosis.—The Report of the Royal Commission (1895) appointed to inquire into the effect of food derived from tuberculous animals on human health, is worthy of careful study. As regards the prevalence of tuberculosis in food animals the records of the Copenhagen and Berlin slaughter-houses show that from 15 to 18 per cent. of the oxen and cows slaughtered are tuberculous, of calves only from 0·1 to 0·2 per cent. are tuberculous, of sheep only 0·0003 to 0·0004 per cent., and of swine 1·55 to 15·3 per cent., the latter figure applying to the Copenhagen and the former to the Berlin swine. For milch cows there are no figures available on a large scale; but of 300 milch cows which were slaughtered in Edinburgh in 1890, on account of the appearance of epidemic pleuro-pneumonia there, 120, or 40 per cent., were found to be tuberculous on post-mortem examination. There is no doubt that milch cows suffer far more frequently than oxen, heifers, or bulls, and that tuberculosis is more frequently found in the carcases of cows than in any other animal

slaughtered for sale. From the experiments made for the Commission by Sidney Martin, it appears that tuberculous deposits are but seldom found in the meat substance—the muscular tissue—of the carcase of an affected animal. They are principally found in the organs, membranes, and glands. In cases of mild, moderate, and localized tuberculosis, if the affected organs are discarded, and if great care is exercised to prevent smearing and contamination of the meat by caseous or other tuberculous material adhering to the butcher's hands, knives, and clothes, there is no reason why the rest of the meat should not be used for human consumption. As at present practised, however, in this country, the slaughtering of a tuberculous animal almost necessarily involves the contamination of the surfaces of the joints of meat with infective tubercular material. In cases of generalized tuberculosis, not only is the risk of contamination of the meat in dressing the carcase greatest, but there is also no certainty that tubercular material may not be present in the muscular substance, or in glands in the connective tissue between the muscles, and consequently the carcases of animals so affected should be condemned and destroyed.

The necessity for skilled and well-trained meat inspectors is dwelt upon by the Commissioners, who were of opinion that the following principles should be observed in the inspection and condemnation of tuberculous carcases of cattle:—

<table>
<tr><td>" (a) When there is miliary tuberculosis of both lungs . . .
(b) When tuberculous lesions are present on the pleura and peritoneum .
(c) When tuberculous lesions are present in the muscular system or in the lymphatic glands embedded in or between the muscles . .
(d) When tuberculous lesions exist in any part of an emaciated carcase .</td><td>The entire carcase and all the organs may be seized.</td></tr>
<tr><td>(a) When the lesions are confined to the lungs and the thoracic lymphatic glands . . . .
(b) When the lesions are confined to the liver . . . .
(c) When the lesions are confined to the pharyngeal lymphatic glands .
(d) When the lesions are confined to any combination of the foregoing, but are collectively small in extent .</td><td>The carcase, if otherwise healthy, shall not be condemned; but every part of it containing tuberculous lesions shall be seized.</td></tr>
</table>

"In view of the greater tendency to generalization of tuberculosis in the pig, we consider that the presence of tubercular deposit in any degree should involve seizure of the whole carcase and of the organs.

"In respect of foreign dead meat, seizure shall ensue in every case where the pleuræ have been 'stripped.'"

Further recommendations of the Commissioners were to the effect that stock owners should be encouraged to test animals by the gratuitous supply of tuberculin, and the offer of the services, free of charge, of a veterinary surgeon; that better sanitary conditions should be enforced in cowsheds; that the closing of private slaughter-houses, and the enforced use of public slaughter-houses should be brought about, to ensure a uniform and equitable system of meat inspection; and that foreign meat should be required to bear a mark of inspection and approval stamped upon it at the time of killing. They do not recommend compensation to the owners of condemned carcases.

The influence of cooking upon tuberculous meat and milk was investigated by Sims Woodhead, who arrived at the following conclusions: "In the boiling and roasting experiments, as ordinarily carried out in the kitchen, the temperature, however high it may be near the surface, seldom reaches 140° F. in the centre of a joint, except in the case of joints under 6 pounds in weight. Ordinary cooking is quite sufficient to destroy any smeared (infective) material that remains on the outer surface of the meat, but it cannot be relied upon in the slightest degree to render innocuous the same smeared material when in the centre of a roll." Rolled meat, the central parts of which had become smeared by tubercular matter, were not sterilized by any process of cooking, unless the roll was less than 4 pounds in weight. The least reliable method of cooking, *qua* sterilization, is roasting before the fire, next comes roasting in an oven, and then boiling.

Probably tuberculosis is not conveyed through the consumption of the flesh of tuberculous animals to any great extent. This view is supported by the fact that the reduction in the mortality from tuberculosis has been very marked during the age-periods in which meat is most largely consumed; and the great reduction in mortality, between 1851 and 1915, has been coincident in point of time with a large increase in the amount of meat consumed in this country.

Bovine and porcine cysticerci, which develop *Tænia mediocanellata* and *Tænia solium* respectively in man, are probably little affected by salting and smoking. There is, however, good ground for believing that exposure for some minutes to a temperature above 150° F. destroys them. The same may be said for the *Trichina spiralis*, only the temperature must be somewhat higher, as the worm is surrounded by a dense capsule which retards the passage of heat.

The most common condition which renders flesh unfit for human consumption is putrefaction. The whole carcase should be condemned in marked emaciation from disease (but not mere leanness), in glanders, anthrax, generalized tuberculosis, measles and trichinosis. Localized inflammatory conditions or suppuration, early actinomycosis, localized tuberculosis, liver-fluke and echinococci, do not justify the condemnation of the whole carcase, if the rest of the flesh is firm and of a good colour.

The meat of animals which have been slaughtered in the early stages of acute inflammatory disease, foot and mouth disease, and epidemic pleuro-pneumonia is probably quite wholesome if well cooked, unless the animals have been drugged with medicines before killing. The evidence as regards the possible bad effects from the use of meat taken from animals which have suffered from rinderpest or cattle plague, swine fever, braxy or splenic apoplexy (sheep), and smallpox (sheep) is conflicting.

A certain amount of the meat condemned in public slaughter-houses may be used for human food under the following circumstances: (1) It may be dealt with in public kitchens under precautions which will ensure a thorough cooking, and the cooked meat or soup made therefrom may be sold at a small charge—as in the Freibanks in Germany, or (2) the meat can be sterilized by steam under pressure, and then sold. If, however, it is unfit for human food under any circumstances, it should be either made into manure under supervision, or, failing this supervision, it should be saturated with petroleum, carbolic acid, or mineral acids, before it is allowed to be removed, in order to ensure that it will not be sold as food.

The arguments in favour of public abattoirs may be summarized as follows: They constitute the only possible means of proper and systematic inspection at the time of slaughter, such inspection being necessary to secure the humane slaughter of animals and to prevent the sale for human food of diseased meat.

As to private slaughter-houses, their number, their distances apart, and the varying times at which slaughtering takes place, combine to make it quite impossible for an official to make those inspections immediately prior to slaughter, at the time of slaughter, and immediately afterwards, which alone suffice to detect most of those diseases which render flesh unwholesome as food. It is quite impossible for an inspector, however skilful he may be, to detect unwholesome conditions of meat when this has been trimmed and prepared for sale in the shops. The consumer would have a guarantee that home killed meat was good and wholesome, and this would probably increase the demand for it. The better provisions for slaughtering and cooling the meat, and the diminished handling, would favour its good appearance when exposed for sale. If public slaughter-houses are constructed near railway stations, the driving of cattle through crowded streets is avoided. On the other hand, butchers as a body do not favour these establishments; and slaughtering is likely to be done elsewhere, unless private slaughter-houses are at the same time abolished, and only stamped meat allowed to be sold. Butchers argue that the handling and carting, entailed by the removal of the meat from the abattoir, tend to destroy the characters of home killed meat, but this argument does not apply if suitable carts are used in which the meat is suspended by hooks from the roof.

The buildings of a public abattoir should include lairs for animals about to be slaughtered, separate places for such as are unsound, separate slaughter-houses for the different kinds of animals, cold storage for meat, buildings for the treatment and disposal of the offal and diseased parts, stables and sheds for horses and vehicles and the drivers' dogs, and a market room with restaurant. There must be an ample water supply, and the means of making ice should be provided.

Fish.

Though many parasites attack fish, the encysted form of the tapeworm called *Bothriocephalus latus*, which is sometimes found in the pike or turbot, is the only one which is known to be harmful.

Oysters and mussels have been known to produce poisonous symptoms, and nettlerash is an occasional consequence of the

consumption of the latter. The common symptoms of poisoning are nausea, vomiting, dyspnœa and muscular weakness. The toxic substance of poisonous mussels is an alkaloid called mytilotoxin; but, as in the case of oysters, the symptoms of poisoning may be due to infection or intoxication from the Gaertner and paratyphoid bacilli. Such mussels generally appear to be unhealthy, with large livers. Both mussels and oysters, fed in sewage-polluted water, have conveyed the infection of enteric fever.

There are few points so easy to detect as commencing putridity in fish; this is fortunate, inasmuch as decomposition sets in rapidly, and appears to be more generally productive of poisonous symptoms than decomposing meat—the symptoms produced being very similar in both cases. The bright gills, the prominent eyes, the elastic resistance of the firmly adhering flesh, and the absence of any but the characteristic odour, are all evidence of freshness. The soft inelastic feel of the fish, and the unpleasant odour, furnish the chief clue—and the most reliable—to commencing decomposition; since it is possible to revive the gills by artificial colouring agents, and to keep the eyes prominent by a small piece of stick, fixed transversely in the head, so that it presses the eye outwards on either side.

Meat Extracts.

Many meat extracts are now upon the market, the tendency being for the public to over-estimate their food value. They consist of the extractives of meat, and not of the meat itself; and they act as stimulants and regulators of digestion rather than as true foods capable of providing the necessary amount of nitrogenous material for the needs of the body.

A meat extract should consist of a golden-brown sticky substance with a pleasant meaty odour. It should never be hard, and should attract moisture strongly from the air. The reaction should be slightly acid. The usual method of preparation consists in heating raw meat, which has been finely divided, with a little water under pressure. The extract thus made is filtered and evaporated *in vacuo* in the open. It is essential that a temperature below 75° C. be employed if all gelatine is to be excluded (Beveridge). The extract thus made contains the flesh bases or extractives and mineral matters of the meat, but

is free from albumin, meat fibre, gelatine, and fat; but in some of the meat extracts on the market these substances and also vegetables are subsequently added in order to give the extract a certain food value. A meat essence is a more liquid extract, containing more water, but has the same colour, odour, and reaction. Meat juices are prepared in the cold by subjecting finely divided meat to strong pressure and ultimately concentrating by evaporation *in vacuo*. They contain the soluble proteins of meat.

These substances, prepared as above, are only to a very limited extent foods or tissue-builders, and produce neither heat nor energy. They are chiefly valuable in sickness or fatigue as adjuvants to other foods, as they excite the flow of gastric juice, aid digestion, and increase appetite. Beveridge gives the analysis of a well-known meat extract as follows: Water, 37·2 per cent.; mineral matter, 22·2 per cent.; fat, 1·07 per cent.; total nitrogen, 7·1 per cent.; equivalent flesh bases, 18·62 per cent.

Sausages.

These are made of the chopped flesh or internal organs of various animals, mixed with condiments, flour, bread, or potato meal, and filled into clean gut or parchment; the sausages are then generally boiled, smoked, or scalded. Saltpetre is sometimes added to furnish a good red colour to the meat, and often colouring agents (carmine, cochineal, or aniline) and preservatives are added. The colouring matter can generally be extracted by warming for several hours with a mixture of equal parts of glycerine and water. Boric acid is often used as a preservative. It is certain that since boric acid prevents objective decomposition, such as is detectable by odour, it permits of the use of stale meat and meat in the early stages of decomposition for the making of sausages.

While the amounts of boric acid usually employed will not enable the use of meat which has reached a stage of marked putrefaction, they permit of the use of stale material in a state of incipient decomposition, and while they may reduce the danger from putrefactive toxins, they do not materially reduce the risks of poisoning from organisms of the Gaertner group or from *Bacillus botulinus*.

Dr. C. A. MacFadden, in a Report to the Local Government

Board (1908), expresses the view that if on the ground of public convenience and trade requirements the use of chemical antiseptics is permitted in sausages, it appears very desirable that their employment should be restricted within narrow limits. If boron preparations are used for this purpose, he suggests that a limit of $\frac{1}{4}$ per cent. of boric acid would probably be ample, and that even then it might be desirable to require that the purchaser should be notified of the presence of the preservative.

It is not a difficult matter to detect early decomposition in *sausages*; the alteration in the odour will sometimes suffice; for if a little of the sausage is boiled with water and some freshly prepared lime-water is added, good meat yields only a faint ammoniacal odour, whereas bad meat will give off a peculiarly offensive ammoniacal odour. Putrefaction generally commences in the middle of the sausage, when a dirty greyish-green colour is often to be noted.

The skins of sausages have been known to contain mineral poisons, but this is very rare.

Eggs.

The best tests for bad and stale eggs are the following:

1. Fresh eggs are most transparent towards their centres if vertically held against the light; stale eggs are transparent at their upper extremities.

2. If 2 ounces of salt are dissolved in a pint of water, fresh eggs when placed in the solution sink, and stale ones float.

Toxic poison has been separated from decomposing eggs.

Milk.

Milk is the natural food of all animals belonging to the Mammalia for a longer or shorter period following their birth. It therefore contains all the constituents of the standard diet, and these in the proportions most favourable for the growth and development of the young animal.

The varying proportions of the different solid constituents of milk as secreted by the human female, the cow, the ewe, the goat, and the mare, are shown in the following table. The presumption is that the natural milk of one young animal is not suited for the nutrition of another animal of a different species. This

AVERAGE PERCENTAGE COMPOSITION BY WEIGHT.

Constituents.	Cow.	Mare.	Goat.	Ewe.	Woman.
Specific gravity ..	1032·50	1036·12	1032·70	1039·30	1032·00
Fat	3·76	1·76	5·50	11·28	3·15
Caseinogen, albumin, etc.	3·50	3·58	4·50	8·83	2·33
Sugar..	4·75	5·87	4·54	3·58	6·36
Ash	0·72	0·39	0·90	1·09	0·32
Water	87·27	88·40	84·56	75·22	87·84
Total	100·00	100·00	100·00	100·00	100·00

is certainly true of the human infant, which thrives far better on human milk than on cow's milk. In cow's milk the caseinogen is in much too large a proportion as compared with human milk; the fat and salts are also in excess, whilst the milk sugar is very deficient.

Two-thirds of the protein of human milk consists of lactalbumin, which is a soluble form of albumin not curdled by acids, and coagulating at 165° F. The other third part of the protein of human milk is caseinogen, which is an insoluble form of albumin,[1] and forms a dense curd with rennin and acids; it is not coagulated by heat. In cow's milk, on the other hand, only about one-tenth part of the protein is in the form of lactalbumin, the remainder being caseinogen (see p. 352).

In the process of digestion, milk is curdled by the gastric juice; the caseinogen and fat separate as curd, whilst the sugar, the soluble albumins, and the salts remain dissolved in the water as whey. Owing to the small proportion of caseinogen in human milk, the curd formed in the stomach is a loose flocculent mass, easy of digestion and assimilation; whilst cow's milk, owing to the abundance of caseinogen, clots in putty-like or wet cheese-like masses. The cow's milk curd is far less easily digested; it may give rise to dyspepsia, flatulence, and diarrhœa, and some of it may be passed unaltered in the fæces. Ass's and mare's milk approximate much more closely in composition to human milk, and give a loose, flocculent and easily digestible curd. Goat's milk is too rich in fat and proteids, but it also forms the proper kind of curd in the human stomach, and the circum-

[1] Caseinogen probably exists in milk in combination with phosphate of lime, which helps to keep it in solution.

stances that her excrement is solid and her tail short, tend to favour the cleanliness of the milk.

For hand-fed infants under nine months of age, if cow's milk is used, it should be given diluted with water, and milk sugar should be added. The dense clotting may be, to a certain extent, prevented by the addition of some mucilaginous substance to the milk, such as pearl barley water well boiled and strained, which

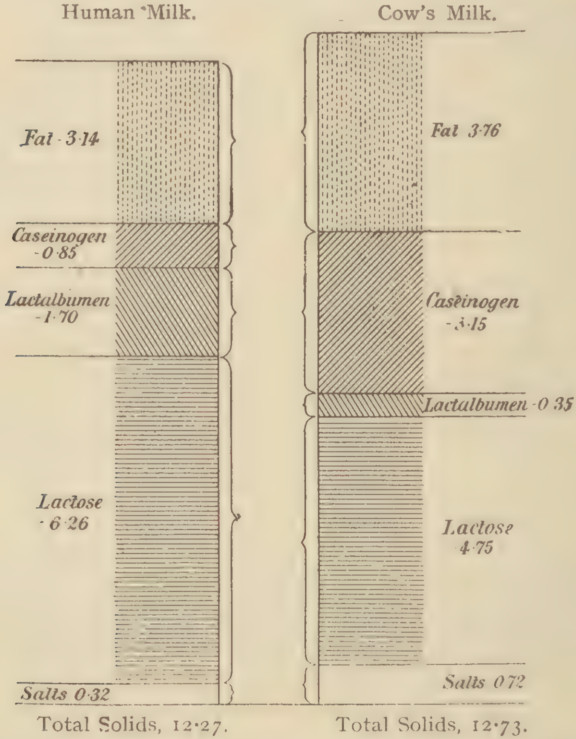


FIG. 62.—PERCENTAGE COMPOSITION OF SOLIDS OF HUMAN AND COW'S MILK.

has the mechanical effect of preventing the particles of casein coming too close together; and the curd thus formed is looser and more easily attacked by the digestive juices.

Wright and Poynton have shown that the dense clotting of cow's milk with rennet, as occurs in human digestion, may be prevented by partial removal of the lime salts in the milk. By adding 2 or 3 grains of citrate of soda to each ounce of milk, citrate of lime is precipitated, and the clot which rennet produces

is then much lighter and more flocculent, resembling the clot formed with human milk.

Humanized cow's milk is now very largely used in the feeding of infants. The principle to be observed in the humanizing process is to prepare a fluid which shall have, as far as practicable, the composition of human milk so far as the chief constituents are concerned, and which shall also be devoid of harmful organic life. To effect this, the insoluble caseinogen of cow's milk must be reduced to the proportion present in human milk, the lactose must be increased to the right proportion, and the resulting mixture must be Pasteurized. Pasteurization ensures the destruction by heat of the pathogenic organisms which are liable to get into milk, but does not sterilize (destroy all organic life). Sterilization may be necessary, if the milk has to be preserved for any length of time, but the high temperature to which the milk has then to be submitted causes coagulation of the lactalbumin, with the result that the milk is clotted, and loses in appearance. The taste of the milk also is altered, the fine emulsification of the fat is partly destroyed, a partial precipitation of calcium and magnesium salts and phosphates results, and the caseinogen is hardened, but smaller clots form in the stomach than in the case of raw milk.

Boiling destroys the ferments and also the antiscorbutic element in raw milk; and only sporing and certain highly resistant forms of bacteria can survive. None of the changes which result from boiling or sterilization occur in "Low Temperature Pasteurization," *i.e.*, the heating of milk to the temperature of 60° C. for thirty minutes, except the great reduction in micro-organisms.

The whey cream mixture is probably the simplest and most satisfactory form of humanized cow's milk. The method of preparing this mixture is as follows: A pint of milk is allowed to stand in a cool place for three hours. The cream which has risen to the top is then separated by skimming. The skimmed milk is then divided into two equal parts. A small piece of rennet is then added to one part, and the curds, when formed, are strained off, leaving the whey. This whey is heated to 150° F. to destroy the rennet ferment remaining in it, and the other half of the skimmed milk and the cream are added to it. Add 175 grains (3 drachms) of milk sugar (lactose) to the mixture, and sufficient lime water to render very faintly alkaline. Then heat to 158° F. for twenty minutes.

The advantages of the whey cream mixture are (1) that the excess of caseinogen in the cow's milk is removed, whilst the soluble and easily digested lactalbumin is retained. (2) The whey makes a better emulsion with the fat (cream) than water would, and yields a finer curd.

Koumiss is a fermented drink prepared from mare's milk in Russia and Tartary; in this country it is now largely made from cow's milk. It is very easily digested and absorbed, and is a valuable food for invalids.

All the solid constituents of milk are dissolved in the water of the milk, with the exception of the fat, which exists as innumerable minute globules floating freely in the fluid.

Cow's Milk.—The average milk secretion of a healthy cow may be taken as 20 to 25 pints daily; but the quantity of milk and its richness in solid constituents depend largely upon breed in different cows, and in the same cow upon its age, the age of the calf, and the season of the year as influencing its food. As a general rule, it may be stated that cow's milk should not have less than 12·5 per cent. of total solids, of which 3·5 per cent. is fat, and 0·7 per cent. is salts; the specific gravity of the milk being about 1032, and the percentage of cream by volume not less than 10 per cent.

To make up the standard diet for an adult man, of 23 ounces of water-free food, about 9 pints of milk must be consumed; but in such a diet, the proteins, the fat, and the water would be far in excess of the requirements of the system. A prolonged course of milk diet—no other food being given—has been found exceedingly useful in certain forms of kidney disease. In some cases skimmed milk only should be taken, and a portion of the casein should be separated by rennet (a preparation from the gastric mucous membrane of the calf). By this means the diet is deprived of much of its fat and proteins; and the other constituents, being very assimilable, give the kidneys little work to do in elimination, whilst the water clears away disease products from the uriniferous tubules and promotes and restores healthy function.

Many persons, from constitutional idiosyncrasy or weak digestion, cannot digest milk. If the milk is first curdled by the addition of a few drops of acetic acid or a little rennet, and the curds and whey thus formed beaten up together, and a little salt and pepper added, a most digestible dish is prepared, by

reason of the stomach being saved the operation of curdling, which is the cause of the disagreement.

When milk is allowed to stand, some 70 per cent. of the cream rises to the top of the vessel in about eight hours. A centrifugal apparatus is now largely used for the separation of cream, quite 95 per cent. of the fat being removed by this method. Skimmed milk generally contains about 1 per cent. of fat, whereas separated milk generally contains less than 0·3 per cent. Slightly more fat might be obtained by skimming if a longer period were allowed for the milk to stand; but after a time, depending upon the temperature, milk undergoes the lactic fermentation, and becomes markedly acid, the sugar being converted into lactic acid by the agency of certain organisms, which grow and multiply in the milk. The milk becomes curdled, and the whey separates from the curd. At a later stage lactic acid is converted into butyric acid by means of another bacterium or bacillus; the milk at the same time becomes turbid, and putrefactive changes set in from the growth of *Bacterium termo* and other saprophytic organisms.

Sour milk has been advocated for the treatment of intestinal dyspepsia. The organisms which break down lactose into lactic acid appear to be chiefly of two kinds—the bacillus of Massol, or the Bulgarian bacillus (Youghourt), and the *Streptococcus lactidis*. The milk is first sterilized by heat, and then inoculated with a pure culture of the lactic acid bacilli, the milk being incubated at 37° C. for several hours, until sufficient lactic acid is formed. In the intestine the lactic acid bacilli appear to have the property of restraining the growth of the organisms which cause fermentation and putrefaction, whilst they themselves are harmless. After a time a growth of the lactic acid bacilli is established in the intestine, as shown by the appearance of these organisms in the fæces. Care must be taken to thoroughly sterilize the milk in the first place, and subsequently to add nothing except a pure culture of lactic acid organisms, otherwise undesirable fermentations may be induced causing the formation of toxic products.

Milk may be sterilized, and thus preserved from fermentation and decomposition, by keeping it at a temperature of 100° C. for fifteen minutes in sterilized vessels. The milk is then raised to a boiling temperature and hermetically sealed. A closed vessel should be used, because in an open vessel a skin forms on the

surface of the milk, and then the vitality of the organisms is not so readily destroyed.

Although "pasteurization" is a term applied to denote a procedure the details of which may vary considerably, it may be best effected by the exposure of milk (previously cleansed by filtration or centrifugalization) to a temperature not exceeding 70° C. for a short period, and then rapidly cooling it to a temperature as much below 15° C. as possible. Under such conditions it is possible (*a*) to reduce the micro-organisms which are capable of being cultivated on artificial media to less than 5 per cent. of those which can be cultivated from the original milk, to thereby destroy or inhibit the fermentation bacteria so as to delay the natural souring of the milk some twelve to twenty-four hours, the milk meanwhile keeping perfectly wholesome; (*b*) to destroy the specific organisms of tuberculosis, diphtheria, enteric fever, cholera, and dysentery, and doubtless also, in large measure, those organisms that are causative of zymotic diarrhœa. It is, therefore, a valuable measure of protection against the recurrence of those milk-borne epidemics which have figured in the epidemiological records of this country; it is a useful means of reducing the grave risks of the infection of tuberculosis in milk; and the evidence is overwhelming that it reduces the suffering and mortality among infants who are artificially fed in the summer months.

In low temperature pasteurization, which is to be advocated, the milk is maintained at the temperature of 60° C. for thirty minutes; but pasteurization at about 70° C. for ten to twenty minutes is more usual.

This may be conveniently effected in the home as follows:—

Take a deep saucepan, fit in at the bottom a piece of wood about half an inch thick, and broad enough for two half-pint bottles to stand upon; place the bottle or bottles containing the milk, and stoppered, within the saucepan, and then pour in some very hot (but not boiling) water; put over fire, and when the water comes to the boil remove the saucepan and place on hob for fifteen minutes. Then take it to the sink and put it under the cold water tap so that the hot water gets rapidly replaced by cold. Keep the bottle in water until a meal has to be prepared. By this method the pasteurization is efficient, and the temperature of the milk barely exceeds 170° F.—so that the physico-chemical qualities of the milk are not changed, as is the case when the boiling temperature is reached.

The enzymes in milk, which are mostly derived from bacteria, and are probably of little, if any, value to the infant, are not

destroyed by pasteurization below 66° C. for thirty minutes; but the traces of anti-bodies which exist in milk (antitoxins, opsonins, agglutinins) are destroyed at about 60° C. These latter bodies also appear to be unimportant, for they are not absorbed in the alimentary canal, but rather destroyed there. Dr. J. Lane-Claypon, in a Report to the Local Government Board (1913), finds that all the available evidence in this and other countries supports the view that the boiling of milk in no wise reduces its nutritive value to the young animal.

The question of the production of infantile scurvy by the prolonged use of sterilized milk has received much attention. Where the condition occurs it is likely to be due either to the admixture of starchy food with milk or to the use of stale sterilized milk; and it is always a good rule where an infant is brought up entirely on previously heated milk to administer daily a small quantity of grape, orange, or lemon juice, so as to make up for any deficiency in the antiscorbutic principles (vitamines) in raw milk.

For trade pasteurization, which has for its object the improvement in the keeping qualities of the milk, a temperature of about 70° C. is usually maintained for only about a minute or even less. Milk is also preserved in a desiccated form as a powder, the water being expelled by evaporation; or it is highly concentrated, mixed with sugar, and then sold as "condensed" milk.

Condensed Milks.—The degree of concentration is usually to about 33 per cent. of the volume of the original milk; but there is upon the market evaporated milk which has not been concentrated to more than 50 per cent. The degree of concentration should be stated upon a label. The table on p. 358, taken from Dr. Coutts' Report to the Local Government Board (1911), indicates the percentage chemical composition of the chief classes of condensed milk on the market.

As a rule condensed milks have been kept free from preservatives. In the sweetened milks the sugar is sufficient to inhibit the growth of bacteria, and in the unsweetened the milk has been sterilized at higher temperatures. The processes carried out in condensing the milk appear to be sufficient to destroy *Bacillus coli*, *B. tuberculosis*, and other pathogenic organisms, but spore-bearing bacilli, streptococci, sarcinæ, yeasts, and other saprophytes, are often present, so that condensed milks must not be regarded as necessarily sterile. It is probable that the bulk

of the organisms present have gained admission during the processes of cooling and of filling the tins.

It is evident from the following table that the full cream unsweetened condensed milk is the one most suitable for the feeding of children. The sweetened milks contain cane-sugar, which is not found at all in the mother's milk for the human infant; and the large amount present is a cause of the fermentation, flatulence, and diarrhœa so common in infants fed on these brands. But even the unsweetened brand is defective in two important qualities—namely, (1) that the original enzymes of the fresh milk have disappeared in the processes of heating and condensation, and (2) there is a loss of the antiscorbutic properties

	Full Cream.				Machine Skimmed.	
	Sweetened.		Unsweetened.		Sweetened.	
	Lowest.	Highest.	Lowest.	Highest.	Lowest.	Highest.
Total solids ..	68·1	83·6	29·2	38·0	59·6	79·1
Protein	7·3	11·4	8·0	10·0	7·6	12·3
Fat	8·0	13·7	8·2	11·9	0·1	6·5[1]
Lactose	11·6	17·6	11·1	16·0	10·9	17·0
Ash	1·6	3·4	1·6	2·5	1·6	2·9
Cane-sugar ..	36·1	44·6	Nil	Nil	30·4	52·6

of fresh milk. The antiscorbutic properties of fresh milk have intimate relation to the healthy growth and nutrition of the infant, even if the enzymes are of little value.

It has been suggested that the condensed skimmed milks should be compulsorily labelled "Unfit for Infants." The injurious results upon many infants of feeding them with condensed skimmed milks are malnutrition, resulting in emaciation and atrophy, or, in some cases, rickets and scurvy-rickets. Many such infants die before their first year is completed from convulsions, diarrhœa, bronchitis, and pneumonia. Those which survive infancy are often stunted, ill-developed, and mentally backward. Enlarged tonsils, adenoids, defective formation of the jaws, with irregular dentition, and all the evils these conditions give rise to, are undoubtedly commoner in children whose diet has been deficient in fat, and relatively much too rich in carbo-

[1] This milk was only partially skimmed.

hydrates (cane-sugar), than in those whose early feeding was more in consonance with physiological requirements.

Dried Milks.—Dried milk is cow's milk which has been deprived of water by some drying process, the result being a more or less dry powder containing all the solids of the milk. The usual commercial preparations are (1) dried machine-separated milk, containing about 1 per cent. of fat; (2) dried half-cream milk, containing about 15 per cent of fat; and (3) dried full-cream milk made from whole fresh milk, containing from 27 to 30 per cent. of fat. In one drying process (Hatmaker) the milk is passed between two revolving cylinders heated internally by steam, the surface temperature of the cylinders being considerably over 100° C. The milk spreads in a thin film over the surface of the cylinders, and the water of the milk is quickly evaporated, leaving a thin sheet of dried milk, which is removed by knife blades, adjusted to scrape off the deposited film. This is subsequently broken up and passed through a sieve, thus giving a uniform, finely granular powder.

In another drying process (Merrell Soule), the milk, after separation and remixing of cream and separated milk, is condensed *in vacuo* to a certain degree, and then, without cooling, is filtered and pumped through an exceedingly fine nozzle into a chamber through which hot, dry air circulates. The milk spray falls as a fine powder on the floor of the drying chamber, which does not require any breaking up, grinding, or sieving.

The dried milk is packed in wooden boxes, barrels, or hermetically sealed tins, and is generally sold to the public in tins with lever lids, in cardboard cartons, or in paper packets. Paper or cardboard packing is sufficient if the dried milk has not to travel far or be kept for long. If kept long, especially if not kept in a very dry place, dried milk packed in paper or cardboard is apt to acquire an unpleasant taste and tallowy odour due to commencing rancidity in its fat contents, or possibly to oxidation changes in the fat globules.

Dried milk is "reconstituted" by dissolving the powder in warm water, the fluid thus obtained resembling fresh milk, but with the odour and taste of boiled milk. Many of the fat globules of this reconstituted milk are often about twice the size of the largest globules of fresh cow's milk, and tend to form an oily mass on the surface of the milk. To reconstitute, 1 part of dried milk is used to 7 parts of water, thus producing a

12·5 per cent. solution. The specific gravity of this mixed dried milk and water will be approximately 1·030, and allowing 3·7 per cent. for moisture in the dried milk, the reconstitution corresponds to a fresh milk containing 11·7 per cent. of total solids. The curd produced by the action of rennet on this milk is flocculent and finely divided, differing markedly from the firm, tough, cohesive rennet curd of fresh milk. This accounts for the now well-recognized fact that for most infants dried milk is more digestible than fresh milk. Some of the lactalbumin—perhaps a half—is rendered insoluble by the drying processes the dried milk has been submitted to. The milk sugar appears to undergo no alteration. The soluble salts of calcium are rendered insoluble by the drying process. The ferments of the milk are destroyed, but this loss is of no importance (Lane-Claypon). The vitamines present in fresh milk are diminished by the drying process, but sufficient are left—at any rate, if the dried milk has not been kept too long—to ward off any tendency to scurvy in dried milk fed infants.

It is generally agreed that the fine granular milk powder made by spraying the milk into hot air (Merrell Soule process) does not keep so well as that made by the hot roller (Hatmaker) process. There seems to be a greater tendency to the oxidation of the fat and the development of a tallowy flavour. On the other hand, the dried milk produced by the spraying process is rather more soluble in water, especially in cold water, than that produced by the hot roller process.

The average composition of five dried milks now on sale (Glaxo, Ambrosia, Cow and Gate, Tru-Milk, and English Milk Powder) is as follows: Fats, 26·8 per cent.; proteins, 26·4 per cent.; sugar, 37·8 per cent.; minerals, 5·8 per cent.; water, 3·9 per cent.

Dried milks are now very extensively used for infant feeding, and for expectant and nursing mothers, and the results on the whole have been exceedingly good. The milk so prepared is of uniform composition, free from all dangerous organisms, and is easily digested by the great majority of infants. It should, however, not be kept too long, and it is advisable to add some fresh fruit or vegetable juice to the diet of infants fed continuously on dried milk.

Fresh cream contains a very variable proportion of fat. Generally the amount of fat present is between 30 and 50 per cent. Clotted cream generally contains from 45 to 60 per cent. of fat.

The usual preservative for cream is a mixture of boric acid and borax in such proportions as to produce a nearly neutral solution. The mixture is then heated to expel water, and finally the mass is reduced to a fine powder. A small quantity of saccharin may be added to mask any incipient sourness. Sodium salicylate or sodium benzoate have occasionally been added to reinforce the preservative effect of the boric acid, but these are no longer allowed under the Regulations of 1912.

Hydrogen peroxide is used as follows:—The cream, immediately after separation, is treated at 120° F. with the peroxide, 100 c.c. of a 3 per cent. solution being added to each gallon of cream. The mixture is maintained at 120° F. for ninety minutes in a closed vessel. At the end of this time a drop or two of a solution of catalase is added to each gallon of cream to decompose any remaining peroxide.

Cream may also be preserved by cold storage, and by sterilization, *i.e.*, by exposure to a temperature of 212° to 220° F. for about half an hour. Sterilized cream tends to separate into a watery and a fatty layer on keeping, unless it has been passed through an homogenizer previous to heating. It generally has the characteristic taste of boiled milk.

There is at the present time a very copious literature dealing with the diseases and injurious effects attributable to the use of cow's milk. Forming, as it does, so large a proportion of the daily food of infants, young children, and invalids of all ages, and consumed, as it generally is, by all ages and all classes, in an uncooked state, the importance of the inquiries that have been made and of the facts that have been elicited can hardly be overestimated. The following considerations will be found of use in arriving at a proper understanding of the subject.

Milk has a remarkable power of absorbing gases and vapours, organic and inorganic. It is, besides, a fluid which, while possessing all the essential constituents of food, forms a most suitable cultivating medium for low forms of life, fungoid or bacterial. So that it is not too much to assume that specific disease germs, which have gained access to the milk, may so grow and multiply as greatly to increase its power of infection.

Under natural conditions the mother's milk, as sucked in by the infant, is free from all organic life; but where cow's milk is substituted, immense numbers of living germs may be introduced into the stomach, which at this tender age may be unable

to cope with them, and ill-health and disease ensue. These germs gain access mainly through dirt, and a bacterial standard of cleanliness has been adopted in some American towns, 500,000 per c.c. being the limit of organisms permitted in raw milk during the cold winter months, and 1,000,000 during the warmer six months of the year; and a limit of 50,000 per c.c. has been adopted for pasteurized milk. A specially produced tubercle-free "certified milk," as sold in America, may not contain more than 10,000 micro-organisms per c.c., and must be delivered to the consumer (who, of course, pays a much higher price for it) at a temperature not exceeding 10° C.

The chief sources of the infection of milk are dirt and water—dirt finding its way into the milk during and after milking, and the water through the washing of the cans, or by wilful addition to the milk with the object of increasing its bulk.

FIG. 63.—ASPERGILLUS GLAUCUS (× about 150 diameters).

FIG. 64.—PENICILLIUM GLAUCUM (× about 200 diameters).

More cleanly methods in connection with the collection, transit, and storage of milk are urgently demanded. It has been demonstrated that the dirt in milk chiefly gains access at the farm, in the homes, more especially of the poor, and to a less extent during transit. It has not yet been found practicable to establish a general dirt standard; but successful prosecutions have been taken under the sections of the Public Health Act which deal with unwholesome food, where the dirt in milk has been found to be very considerable. In order to reduce the amount of dirt in milk it is necessary that the milker should have clean hands and clean overalls at the time of milking; that he should perform "dry" milking into sanitary milk pails with an opening not exceeding 8 inches in diameter; and that the cow should have a clean udder. The daily grooming of cows is now undertaken by some of the best dairy farmers; the clipping of the hairs on

the flanks, round the udders, the hind quarters, and the tip of the tail also aids in protecting the milk from dirt. Clean bedding in the sheds is also necessary. Immediately after collection the milk should be strained through a fine metal gauze, filtered through a layer of cotton-wool, and then cooled to 13° C., or as much below this as possible. It follows that all utensils must be scrupulously clean. For cleansing purposes steam or boiling water is essential. In railway transit the milk should be conveyed in sealed dust-proof cans; and in the home it should always be stored in clean receptacles, kept cool and covered, and thus protected from the access of dust and flies. There is danger in the promiscuous mixing of the milk from different farms, as practised by large milk dealers; any infection in the milk is thus conveyed to a wider area of consumers than would be the case if this practice were abandoned. In order to obtain a cleaner and therefore safer public milk supply, education and training in the hygiene of milk collection, storage, and distribution is demanded, and the general public must be taught to demand clean milk and to keep it clean, for the poorer section of the public permit a large amount of contamination to take place in their homes. Sanitary authorities are doing more to educate the general public on matters affecting the public health. One advantage of a municipal milk depot or model dairy is the opportunity afforded to the sanitary authority of presenting an object-lesson to the local milk sellers of a model dairy; for even if the farm supplying the milk is not a municipal one, the local authority can usually impose what conditions it deems necessary upon the milk vendor who obtains the contract.

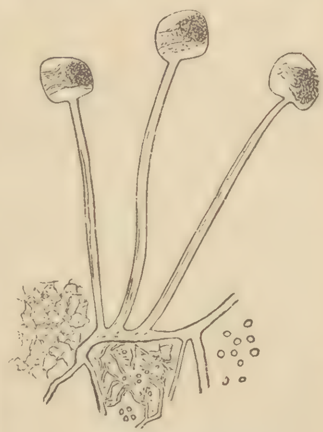


FIG. 65.—MUCOR MUCEDO (× about 80 diameters).

As to cowsheds, each cow is usually required to have a space of 8 feet by 4 feet in a separate stall, and two cows 8 feet by 7 feet in a common stall. The minimum air space should be fixed at 600 cubic feet, but when the ventilation is imperfect, 800 cubic feet should be required per head. The floors must be imperviously paved and drained to gullies situated outside of the shed; the lower parts of

walls to be of non-absorbent material; there must be no communication of the cowshed with a water-closet or privy; and 12 gallons of water per day must be provided for the use of each cow. All milk vessels to be steamed or scalded immediately after use.

The Model Regulations of the Local Government Board issued in 1899 distinguish, as regards overcrowding in cowsheds, between those from which the cows are habitually turned out during a portion of each day to graze on grass land, and those in which the cows are not turned out. As regards the latter, the Regulations provide for 800 feet of air space for each cow, no space to be reckoned which is more than 16 feet above the floor. The Local Government Board will sanction 600 cubic feet of air space per cow under certain conditions, but the floor space must not be less than 50 square feet per cow. For the former class of cowshed no such provision is made.

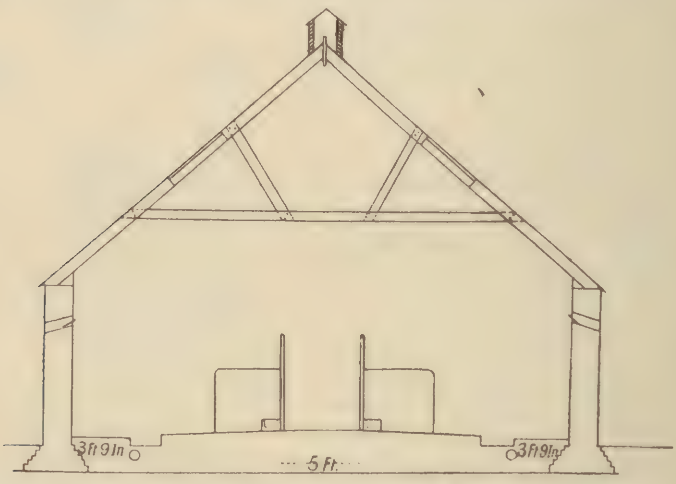


FIG. 66.—A SANITARY COWSHED, DOUBLE BYRE WITH CENTRAL FEEDING PASSAGE.

As regards the milking of the cows, it is provided that at the time of milking the udder and teats of the cow must be thoroughly clean, and the hands of the milker must be clean and free from all infection and contamination.

Milk, as being derived from the living animal, must be also, to a great extent, a reflection of the animal's state of health. But we can go further than this, and say that milk is, for a certain period, derived from an animal in the puerperal condition consequent on parturition—a condition known to be liable to certain disorders, chiefly inflammatory, and particularly prone to take the infection of contagious disease.

Milk which has become acid from lactic and coincidental

fermentations is liable to cause sickness and diarrhœa in children; and if *Oïdium albicans* is present in the milk, it may attack the mouth and digestive tracts of infants, causing thrush. Other fungi and moulds—penicillium, aspergillus, mucor, etc. (see pp. 362, 363)—when present, may cause severe gastric irritation. Similar symptoms have been produced by pus and fluids from inflamed udders and udder abscesses contaminating the milk.

In 1881 Mr. Ernest Hart compiled tables with particulars of 50 epidemics of enteric fever, 15 of scarlet fever, and 6 of diphtheria—4,800 cases of infectious disease in all—which had been traced to an infective or a supposed infective quality of the milk supplies; and since that date there have been numerous other milk epidemics recorded.

In the case of *enteric fever*, the most usual means by which milk obtains its specifically infectious quality is the washing of the milk cans, etc., or the intentional dilution of the milk, with water polluted by typhoid dejecta. In other cases the infection has been attributed to the storage of milk in rooms or dairies the air of which was subject to drain or sewer emanations; but probably the most frequent cause of milk obtaining infective power is the presence of a person in the milk shed or dairy who is a "typhoid carrier." The handling of the teats of the cow or of the milk vessels by hands tainted with infected excreta (not properly cleansed after attending to the calls of nature), is a very obvious means by which the milk receives a massive infection. Kober, in 1901, published the facts of 195 milk epidemics of enteric fever, in 148 of which the infection was ascribed to insanitary farm conditions. There is no evidence that enteric fever is a disease of cattle communicable to man through the milk secretion, or by means of pollution of the milk by the alvine discharges through careless milking.

In those epidemics of *scarlet fever* which have been traced to milk, it has been usual to find that the milk was infected through human agency by a previous case of the disease at farm or dairy. The cows were milked by a person who was attending on a scarlet fever patient, who had the disease amongst his family—possibly in an unrecognized form, as sore throat without rash—or who was himself suffering from it in a mild or disguised form. Occasionally the milk appears to have derived its infective quality from being kept in a room in which clothes or refuse matters from the sick were lying.

But besides such easily understood methods, the history of the Hendon, Wimbledon, and Wiltshire (1909) outbreaks appeared to show that cows are liable to a disease identical with or very closely resembling human scarlet fever, and that the milk from animals so suffering might prove to be the cause of epidemic outbursts of the disease amongst those who consumed it. Dr. Klein isolated an organism—a streptococcus—from the udder lesions (ulcers) on the Hendon cows, which he believed to be the true pathogenic organism. A streptococcus has also been found in the diseased organs and tissues of human scarlatinal cases.

Subcultures of this organism obtained from human scarlatinal cases, when inoculated into recently calved cows, are said to produce the characteristic ulcers on the teats, along with other manifestations of the Hendon cow disease; and calves fed on these subcultures obtain the same disease. However, this matter has been, and still is, the subject of controversy. The opponents (including nearly all the members of the veterinary profession) of the views of Dr. Klein and of Mr. Power, who investigated the Hendon outbreak, hold that a possible human source of the disease at Hendon was not absolutely excluded, and assert that other cows suffering from the Hendon disease have not given rise to any scarlet fever outbreak. The weight of opinion is opposed to the view that cows are capable of imparting the infection of scarlet fever to their milk.

In the most recent instance of a scarlet fever epidemic being apparently due to a cow disease, in which parts of London and its south-western suburbs were extensively invaded in June, 1909, it was not possible definitely to exclude a human source of infection; but the Hendon disease was undoubtedly present in several of the cows on the Wiltshire farm which supplied the milk, just anterior to the onset of the first cases.

A possible explanation of the association of scarlet fever in human beings with the milk of cows that have ulcerated teats lies in the supposition that whilst the ordinary ulcer on the teat is a cow complaint, which has no relation at all to scarlet fever, such an ulcer may become inoculated by the scarlatinal virus in the process of milking by a person who is suffering in a mild, unrecognizable form from that disease. The ulcerations may provide a nidus for the growth of the scarlatinal organism, and give the milk an infective power owing to the ulcerated surfaces being handled during milking. This would account for the fact

that, whilst in the great majority of instances cows with ulcerated teats yield a milk which causes no disease, in very occasional instances such cows seem to yield a milk which has the capacity to produce scarlet fever.

In a large percentage of the milk epidemics of *diphtheria*, it has not been possible to trace the source from which the milk derived its infective quality. This is not to be wondered at; for slight cases of diphtheria are very difficult to trace, the diphtheritic character of a sore throat not being always recognizable even to a medical attendant. There is practically no evidence to show that diphtheria may be a cow disease transmissible to human beings, although calves have been known to suffer from a throat affection presenting post-mortem appearances very similar to those found in human diphtheria. The question as to whether garget or mammitis in cows is capable of producing diphtheria in the consumers of milk taken from gargety udders may be answered in the negative, but there is some evidence to show that it may be responsible for outbreaks of septic sore throat. It is possible that here again the infection may have a human origin.

Recent experiments of Savage, however (L.G.B. Report, 1908-9), tend to show that the common organism of mastitis in cows—the *Streptococcus mastitidis*—is not a cause of human sore throat or other human illness.

Stall-fed dairy cows in towns are very susceptible to *tubercle*. Veterinary authorities have stated that at least 25 per cent. of all dairy cows kept in cowsheds are the subjects of this malady. These animals are stalled day and night in stables often uncleanly and badly ventilated, and they are perpetually being drained of large quantities of milk. Prolonged lactation in the human female is well known to be a frequent precursor of phthisis; and it is not wonderful that under such circumstances, and with the additional factors of confinement, want of exercise and bad air, cows should succumb to a malady to which they are in a high degree susceptible. It often happens that the best bred animals, which are usually the best milkers, are those which are most affected. In the early stages the symptoms of the disease are ill defined, the health of the animal is not much interfered with, and the milk secretion is as abundant as ever. Nutrition is not interfered with until the disease is well advanced, and even then the amount of milk yielded, although poor in quality, may not be

diminished, and the dairy farmer continues to keep the animal in stock.

The Royal Commission (1895) found that there was no evidence of danger to the consumer even when the milk is derived from a tuberculous animal, so long as there is no disease of the udder. But the affection of the udder may be present in a cow not otherwise markedly affected with tuberculosis; and the infection once implanted in the udder may spread with alarming rapidity. The milk of cows with tuberculosis of the udder possesses a high degree of virulence; and appears to be virulent even when no tubercle bacilli can be demonstrated in it.

More recent research indicates that the milk of tubercular cows which have no apparent udder disease may be infective. Tubercle bacilli may also be discharged in large numbers in the alvine excreta of tubercular cows; and as it is difficult to exclude all contamination of milk by such excreta, there is always a possibility of the milk of tubercular cows becoming infective in this way, even apart from any elimination of tubercle bacilli by the mammary glands.

The Commissioners held that all udder diseases should be notified, and that anyone selling milk from a cow with diseased mammary glands should be liable to a heavy penalty; they advocate systematic inspection of cows by veterinarians as a means to this end. This recommendation was first given effect to by the Dairies, Cowsheds, and Milkshops Order of 1899, by which Article 15 of the Order of 1885 is amended, so that the expressions in the article which refer to " disease " shall include, in the case of a cow, such disease of the udder as shall be certified by a veterinary surgeon to be tubercular. Such tubercular disease ought to be suspected when a painless hard lump, slowly enlarging, can be detected in one or more of the quarters of the udder. To confirm the diagnosis, it will be necessary to draw off (with aseptic precautions) some of the milk from each of the four teats, and submit each sample to bacteriological examination.

As regards the sterilization of tuberculous milk, it would appear that absolute safety is only to be attained by raising the milk actually to the boiling point. The Commissioners were of opinion that the innocence of tubercular milk treated in this manner was not entirely demonstrated to their satisfaction. When the tuberculous material in milk is raised to temperatures insufficient for the actual destruction of the virus, it is possible

to obtain from the most deadly tuberculous material a weaker sort of tuberculous matter, so tardy in its operation upon test animals as to simulate the slower forms of consumption seen in the human subject, or when used to feed pigs—animals having some specialities of throat (tonsillar) structure like that of man —giving rise to chronic enlargements of the cervical glands, resembling the scrofulous glands so common in children. These observations, the Commissioners think, are suggestive of the possibility of widely prevalent forms of human tuberculosis having an origin in milk.

From the Third Report of the Royal Commission on Tuberculosis it appears that the milk of cows *obviously* suffering from tuberculosis frequently contains tubercle bacilli, even although no disease is present in the udders. By "obviously suffering" is meant the display of clinical symptoms of disease, not merely a reaction to tuberculin. It is, however, generally recognized that the liability of the milk to contain tubercle bacilli is far the greatest when one or more quarters of the udder have become tubercular.

In every dairy farm of any size, where no special precautions are taken to control the spread of tuberculosis, there will probably be tuberculous cows, some of them most likely with tuberculous udders; and as it is the common custom of dairymen to mix together the milk yielded by different cows, it is not too much to assume that tubercle bacilli may be widely distributed in the milk supply. As a matter of fact, the bacilli have been found by many observers in some 10 per cent. of the dairy samples examined by them.

The bacilli of bovine tuberculosis are practically identical—according to all bacteriological methods at present known—with those found in tubercular formations in the human organs, although the disease presents anatomical differences in man and cattle. But these differences are probably due to differences of soil in the human and bovine tissues, the bacilli engrafting themselves in those tissues which present conditions most favourable to their growth and development.

The human bacillus differs from the bovine bacillus in that it is longer, thinner, and grows more luxuriantly; it is also of relatively lower virulence. There are, however, connecting forms which clearly indicate that these two types belong to the same species, and that these differences are merely modifications

of their characters. The bovine bacillus produces by feeding or inoculation the typical tuberculosis lesion in many animals other than the bovine; this is true even of monkeys and anthropoid apes. The human bacillus produces the typical tuberculosis lesion in several animals—*e.g.*, the guinea-pig and monkeys. It can infect bovines, though usually in a limited retrogressive form. In a certain small proportion of the cases of human tuberculosis the bacillus is the bacillus of bovine tuberculosis, in all respects identical and indistinguishable from those bacilli taken from a pure bovine source.

From post-mortem examinations it appears that in 25 per cent. of all human tuberculosis cases under five years of age, and in over 40 per cent. of abdominal, gland, and joint tuberculosis cases during this age period, the bovine species of germ is present. This being so, a considerable amount of tubercular infection through milk must take place in infancy and early childhood.

The autopsies of young children show that primary tubercular intestinal ulceration of the intestines is very rare; it is, however, quite possible that in children tubercle bacilli may pass through the intestinal mucosa and the mesenteric glands, and thence invade even the bronchial glands and the lungs, leaving little or no trace of their passage in the intestines or abdominal glands. What appears, then, to be a primary deposit in the chest may in reality have been due to an infection introduced into the alimentary canal by means of food. But it is a noteworthy fact that the deaths from abdominal tuberculosis during recent years have shown a greater reduction than those from all other forms of the disease. Moreover, whilst the children of the poor are the most notable sufferers from *tabes mesenterica*, they are not nearly such large consumers of milk as the children of those higher in the social scale, who suffer much less from this and other complaints suggestive of abdominal tuberculosis.

It is quite possible that any excess of abdominal tubercle amongst the children of the poor, if there is such an excess, is due to infection from human sources, the children contracting tubercle from being allowed to crawl about dirty, dusty rooms, infecting their mouths from their fingers and from dirty rubber bottle teats.

Evidence obtained by Delépine shows that bovine tuberculosis is, on an average, more prevalent in districts where shippons are generally in a bad state, small, or badly ventilated and dirty;

and where also it is the usual practice to retain many aged cows on the farms.

In order to materially reduce the dangers arising from the consumption of the milk of tuberculous cows, the following are measures which have been suggested and in some cases adopted:

1. A quarterly veterinary inspection of all cows the milk of which is being sold or offered for sale for human consumption; and power to collect samples of milk for bacteriological examination.

2. The isolation from other milch cows of those suffering from "open" tuberculosis, or showing clinical symptoms of tuberculosis; the branding of such cows, and the prohibition by law of the sale of their milk for human consumption, or for the feeding of other animals unless effectively sterilized.

3. The making of diagnosable tuberculosis a notifiable disease in the case of milch cows.

4. The compulsory notification of all forms of udder disease in milch cows, and the prohibition of the sale of milk in these cases, except on a veterinary certificate to the effect that the disease is not of a character likely to affect the wholesomeness of the milk.

In order to eradicate bovine tuberculosis the following suggestions have been favoured:

1. The provision of open-air sheds. It has already been demonstrated by actual experiment that the cows are in a decidedly better condition by being kept more in the open, and that their coats become thicker, while the milk does not decrease in amount.

2. Quarterly inspections and tuberculin tests every six months. The slaughter of all infected bovines. Partial compensation. A system of mutual assurance amongst farmers is advocated, to reduce the loss involved in compensation.

3. Some useful results appear to have been obtained from efforts to render bovines immune to the disease, as by Behring's vaccination, but the immunity disappears within two years, and it has been shown that the human tubercle germ employed may find its way into the milk within twenty-four hours, and continue to be present in the cow's milk for months. The value of tuberculin appears to be limited to the diagnosis of the disease in bovines.

The system of eradication recommended by Professor Bang

includes a testing of herds in the spring and autumn of each year with tuberculin; the segregation of those which react, and disinfection of infected sheds; " wasters " and cows with tuberculosis of the udder to be dried off and sold for slaughter, and the selection of the tuberculosis-free cow for calf-rearing.

By Ostertag's scheme only cases of " open " tuberculosis—namely, those bovines discharging tubercle bacilli—are segregated and slaughtered. This method, while reducing milk infection, cannot eliminate tuberculosis.

Foot and mouth disease, or *epizoötic eczema*, is a contagious disease, characterized, in cows, by an eruption of small vesicles on the lining membrane of the mouth and the interdigital spaces of the feet; not infrequently the vesicles appear on the udders and teats. In the majority of cases the milk secretion is diminished as the disease progresses, and may become entirely suspended. The fever runs its course in from eight to fifteen days. The contagion exists in its most concentrated form in the lymph or serum of the vesicles (those on the teats are liable to be ruptured in milking) and in the saliva, and it possesses considerable vitality.

Numerous outbreaks among human beings of a peculiar illness have been traced to the use of milk from cows with this disease. The symptoms are generally slight fever, vesicular eruptions on the throat and lips, swelling of the tongue, salivation, nausea, fœtor of breath, pain in limbs, and marked swelling of the lymphatic glands of the neck. It is probable that the transmission of the disease is most certain in those cases where there are vesicles on the cow's teats, which are sure to be ruptured in milking, the virus thus obtaining direct access to the milk.

Goat's milk has been shown to be one of the chief channels of the infection of *Malta fever*.

In the case of cows suffering from *cattle plague* and *anthrax*, the milk secretion is suspended at a very early stage. In *cow-pox* the milk secretion is said to be rapidly diminished or suppressed.

A " milk epidemic " is characterized by the suddenness with which it makes its appearance, the sufferers being for the most part attacked about the same time. The infected houses will be found to have been supplied, with a few exceptions, by the particular milk vendor whose supply is at fault. Where infected houses are discovered to which milk has been supplied from different vendors, this circumstance is often due to the fact that

the vendors on their rounds very commonly buy small quantities of milk from each other.

The cases are, of course, localized to the area of distribution of the infected milk supply; women and children in the better class houses are mostly attacked, and the drinkers of raw milk are often picked out. Generally speaking, incubation periods are shortened, attacks are mild, the mortality rate is lower than usual, and the epidemic often ends rapidly.

Sometimes valuable corroborative testimony implicating the milk is forthcoming in the circumstance that some of those in the infected households, who have consumed no unboiled milk, have escaped; and that households supplied from the implicated dairy, but in which no unboiled milk is consumed at all, have entirely escaped.

In several towns in England and on the Continent *municipal depots* have been established for the distribution of humanized (sterilized) milk; and it is claimed that these have had a beneficial effect in reducing infantile mortality. Good cow's milk is diluted and cream and sugar added. The humanized milk is then placed in small stoppered bottles of some five ounces capacity and placed in the sterilizer. The bottles are kept exposed to a temperature of 102° C. in a steam sterilizer for about 45 minutes, and they are then taken out and placed in baskets. The quantity of the milk is adjusted according to the age of the child, and before use each bottle should be placed in a little hot water, the stopper removed, and a teat fitted to the bottle direct. The parents are generally charged 1s. 6d. per week; but this does not meet all the expenses in connection with the depot. Such institutions are of limited value unless they are also made the centres from which many well-informed workers issue to instruct and advise upon how to prepare, and guard the purity of the milk used for infant feeding *in the home itself*.

By a Milk Order of the Ministry of Health which came into force on January 1, 1923, milk may be sold under the following designations: "Certified," "Grade A (Tuberculin Tested)," "Grade A," and "Pasteurized." The conditions imposed are that the producer of any such milk must produce a veterinary surgeon's certificate showing the results of an examination of the herd carried out not more than one month before the date of application for a licence, and where the tuberculin test is required a certificate of such a test carried out within a period

of three months. Moreover, the arrangements for the production, storage, treatment, and distribution must be satisfactory. Where the conditions are not being complied with, any licence may be suspended or revoked by the licensing authority after serving a notice upon the holder stating the grounds on which it is proposed to suspend or revoke the licence. An aggrieved person may, within seven days, appeal to the Minister of Health.

The special conditions under which licences for selling "*Certified Milk*" may be granted embrace : The examination of the cows every three months by a veterinary surgeon; the application of the tuberculin test every six months; no fresh animal to be added to the herd unless tuberculin-tested within the period of three months; any reacting animal to be removed from the herd and the licensing authority to be informed of how it has been disposed of; the herd to be isolated from all other cattle; the milk to be bottled on the farm immediately after production, and suitably sealed; a cap on each bottle shall bear the name of the producer, the day of production, and the words "Certified Milk"; the milk to be delivered to the purchaser in sealed bottles; the milk may not contain more than 30,000 bacteria per c.c. nor any *Bacillus coli* in one-tenth of a c.c.; and it may not at any stage be treated by heat.

The conditions which apply to "*Grade A* (*Tuberculin Tested*) *Milk*" embrace the foregoing provisions with reference to the animals, in addition to the following conditions, which also apply to—

"*Grade A Milk.*"—The producers and vendors of this milk are required to provide a veterinary certificate of inspection of the herds every three months; to remove any animal with any condition likely to affect the milk injuriously, and to forthwith inform the licensing authority how it has been disposed of, and if tubercle bacillus is found in the milk an effort must be made to detect the diseased animals, and to remove them from the herd; the herd is to be kept separate from other cattle; where the milk is not bottled on the farm it must be despatched from the farm in an unventilated sealed container labelled with the address of the dairy, the day of production, and the words "Grade A Milk"; the milk to be delivered to the consumer either in sealed bottles or other suitable containers of not less capacity than two gallons, and duly labelled with the name and address of dealer, the words "Grade A Milk," and the date of production; the milk may not

contain more than 200,000 bacteria per c.c. nor any *Bacillus coli* in one-hundredth of a c.c.; and it may not be heated unless a licence to sell such milk as "pasteurized" has been granted.

Licences for selling milk as "*Pasteurized*" will be granted under the following conditions: The milk must be maintained for at least half an hour at a temperature of not less than 145° F. and not more than 150° F., and subsequently cooled to at least 55° F.; the milk shall not be so treated more than once; pasteurizing plant and methods must be satisfactory; every vessel containing such milk must be labelled "Pasteurized Milk," and the date of pasteurization announced; the milk may not contain more than 30,000 bacteria per c.c. nor any *Bacillus coli* in one-tenth of a c.c.; 50,000 bacteria per c.c. will be permitted in this milk up to January 1, 1924.

Butter.

When the cream of milk is churned—*i.e.*, violently agitated in a suitable apparatus—the fat globules coalesce, entangling in their meshes some casein and serum. The butter so formed is then pressed to squeeze out some of the moisture, and salt added to preserve it. The percentage proportions of the constituents of butter are approximately as follows:

Fat	83·5
Curd	1·0
Ash	1·5
Milk-sugar	1·0
Water	13·0

The amount of water in a sample of butter should never be more than 16 per cent. by weight, and the fat should constitute at least 80 per cent.

The fat of butter consists of a mixture of the glycerides of the fatty acids—palmitic, stearic, and oleic—not soluble in water; and also of the glycerides of certain soluble and volatile fatty acids, principally butyric.

Margarine, *oleo-margarine*, or *butterine*, is manufactured from animal fats (lard, beef, and mutton fats), and vegetable oils (cotton seed, sesame, cocoa-nut, earth nut, etc.). When made from beef fat, this is first finely minced and heated in tanks to about 39° C. The fat then melts, and the water and débris sink to the

bottom. The melted fat is run off as a clear yellow oil, and kept at a temperature of about 30° C. The stearin to a certain extent solidifies at this temperature, whilst the oleo-margarine is separated as a liquid, from which much of the stearin has been removed; for oleo-margarine solidifies at a much lower temperature than stearin. The oleo-margarine is then filtered, pressed, churned up with milk to give it the flavour of butter, coloured with annatto, and cooled with ice, when it is ready for sale.

The great distinction between butter fat and margarine fat lies in the fact that the butter fat contains nearly 8 per cent. of the volatile fats, whilst the margarine fat has rarely more than $\frac{1}{2}$ per cent. In the analysis of these substances this difference is made use of. The same antiseptic and colouring agents are employed in butter as in milk.

Margarine made from animal fats is but little inferior in nutritive qualities to butter; it constitutes a good article of diet. It is somewhat less digestible than butter, and much more generally contains colouring agents and preservatives.

Cheese.

Cheese is an easily digested and most nutritious article of diet.

In the manufacture of cheese, casein and most of the milk fat are precipitated from milk by rennet at a suitable temperature. The curds are then pressed, to squeeze out the whey and reduce the mass to a proper shape. In the process of decay the fat increases at the expense of the casein, and numerous alkaloidal substances, extractives, and aromatic acids are produced, which give a decayed cheese its aroma. These bodies are harmless, but rarely a poisonous ptomaine called "tyrotoxicon" is produced. This substance has also been discovered in cream, butter, and cheap ice-creams, and in milk stored during hot weather. The symptoms produced by tyrotoxicon are allied to those of atropine poisoning; they include vertigo, nausea, vomiting, diarrhœa, collapse, muscular cramps and rigors. Tyrotoxicon is diazo-benzene-butyrate, and its effects have been chiefly observed in America. Cheese poisoning, with symptoms of acute diarrhœa, vomiting, violent abdominal cramp and pain, occurring within six or seven hours, is probably due to virulent strains of bacilli of the coli or Gaertner groups, which produce powerful toxins. How such organisms find their way into cheese

is not yet understood. "Botulism" has been attributed to the eating of a home-made cheese.

Various kinds of parasites grow in decaying cheeses, but they do not seem ordinarily to produce any harmful effects. The more common are: *Aspergillus glaucus* (causing blue or green mould), *Sporendonema casei* (causing red mould), and the cheese maggots (*Piophila casei*).

Wheat Flour and Bread.

Wheat flour contains about 15 per cent. of water, 8 to 12 per cent. of gluten (vegetable albumin), and about 70 per cent. of starch, sugar, and dextrine. It is very deficient in salts and fat. In the finest flour nearly all the outer envelopes of the wheat grain are separated. This separation of the bran, whilst it renders the flour fine in texture and white in colour, deprives it of much nutritious matter, for bran contains 15 per cent. of nitrogenous substances, 3·5 per cent. of fat, and 5·7 per cent. of salts.

The wheat grain is surrounded by a tough, branny envelope, known as the "pericarp," which forms about 15 per cent. of the grain; within the pericarp is the endosperm, consisting of large, thin-walled parenchymatous cells packed with starch grains, forming about 80 per cent. of the entire grain. At the broad end of the grain is the embryo or germ, forming about 1½ to 2 per cent. of the grain.

The wheat grain is converted into flour by milling, and so made suitable for bread-making. The entire grain may be ground up in milling, and used as such for making bread, being then known as *wholemeal*. A portion of the branny husk only may be separated in milling, the resulting product being called *fine meal* or *entire wheat flour*, which latter is evidently a misnomer. Ordinary *white flour* is obtained by the removal of as much of the branny envelope and cellulose portions of the grain as possible, leaving only the starch grains found in the endosperm. In practice, however, such perfect separation is not attained, and the very whitest flour always contains other parts of the grain besides the starch grains of the endosperm.

The products other than white flour obtained by milling are termed in the trade *offal*. The chief of these are *bran*, *pollard* (bran in a finer state of division), *germ*, *fluff* or *fibre* (the cellulose

walls of the parenchymatous cells of the endosperm), and *sharps* or *middlings* (mixtures of all the above).

Stone-milling, in which the wheat grains are ground between two millstones arranged horizontally, the lower stationary and the upper revolving, has now been largely replaced by roller-milling, the wheat being crushed between revolving fluted iron rollers. In stone-milling the grain is crushed into wholemeal, and the separation of this into bran, pollard, middlings, and flour is effected by sifting through cloths with meshes of different degrees of fineness. In roller-milling the grain is reduced to flour in gradual stages, during which the offal is continually removed by sifting and by the use of air currents. By this method a more complete removal of bran and a greater yield of highly refined flour can be obtained than by stone-milling.

The products of the mill from which bread is made are classified as follows: (1) *Wholemeal*, produced by grinding the entire wheat grain. (2) *Fine meal*, or *entire wheat flour*, a portion of the bran only having been removed. This flour can be prepared both by stone and roller mills, but the appearance and quality vary according to the variety of wheat used (red or white), and according to the amount of offal removed. It contains a portion of the germ. "*Standard*" flour is of this class, and contains 80 per cent. of the wheat milled, the 20 per cent. removed consisting of bran and cellulose. It contains all, or nearly all, the germ and semolina. (3) *Households* is the commercially lower grade of flour obtained from roller-mills. It contains a small amount of bran, and is darker than (4) *Patent grade flour*, which is the flour most esteemed by bakers for bread-making, as it contains the least amount of offal, and possesses the most water-absorbing properties, making a large and white loaf on baking.

As regards the nutritive values of these various products of milling in the form of flours and bread, Dr. J. M. Hamill, in his Report to the Local Government Board, states that the differences which exist are not of much importance to the average adult, with whom bread is only one of many varied constituents of his dietary. The differences are not relatively of great magnitude, and they may, to a large extent, be neutralized by imperfect absorption from the digestive tract. There are, besides, wider differences in the protein contents and energy values of the various flours obtained from wheats of different varieties than between the refined white flour and the wholemeal product of

a given wheat. In other words, a refined "patent" flour obtained from one variety of wheat may contain considerably more protein and available energy than the wholemeal flour of another variety of wheat. The choice of a particular sort of bread should depend largely on the idiosyncrasy of the individual. For those with good teeth, who can masticate well, and to whom a large undigested residue is a benefit as promoting evacuation of the bowels, a wholemeal loaf is to be recommended. For those, on the other hand, who cannot masticate efficiently, and whose intestines are irritated by undigested residues, a loaf made from the white, refined, patent grade flour will be most suitable. To some the "nutty" flavour of the "standard" or "entire wheat flour" loaf is an advantage, as it promotes the secretion of saliva. To others this particular flavour may be disagreeable, and, therefore, of no benefit.

For the poor, and especially for the children of the poor, into whose dietary bread so largely enters, the question is a little different, and the cost of the article must be borne in mind. As a rule, for this class an expenditure on a larger quantity of "households" or other cheap bread will be better than purchasing a smaller quantity of a high-priced bread, especially if the cheap bread contains some of the bran and germ which are relatively rich in protein, phosphorus-containing organic compounds, and mineral matters. For such children, wholemeal bread in which the bran has been finely ground, or, if this prove too irritating to the intestines, "standard" bread, or bread made from "entire wheat flour," is probably the best; but here again it is a question of relative cost as compared with ordinary "household" bread. There is one advantage in the breads containing branny particles —namely, that they are more cleansing for the gums and teeth, and less liable to leave that pultaceous residue on the margins of the gums, which a very white bread made from "patent grade flour" is so apt to do. The fermentation of this residue is undoubtedly a strong exciting cause of caries of the teeth, especially in children whose teeth are never cleansed with a tooth-brush.

As a measure of war economy it was decided in the late autumn of 1916 that the use of 70 per cent. flour was to be discontinued. By this is meant that flour amounting to only 70 per cent. of the weight of the original wheat from which it is obtained, is to be replaced by wheat containing a higher percentage of the original grain. The Local Government Board

was requested to make regulations requiring millers to produce only straight-grade flour and to allow not less than a fixed percentage; and from January 1st, 1917, only flour made to schedule may be used for bread or any other article of food. As many different kinds of wheat are used in this country it was necessary to establish a scale of percentages, and the Government required that the percentage of flour that was to be extracted from different wheats should vary from 73 to 78 per cent. It was calculated that generally the average percentage would raise the yield of flour from wheat by 8½ per cent. Such "household bread" can certainly be digested by the few who cannot assimilate wholemeal, even when finely ground.

The growing practice by millers of bleaching flour has also been inquired into by Drs. Hamill and Monier-Williams on behalf of the Local Government Board. The bleaching is undertaken owing to the demand of the public, and therefore of the bakers, for very white bread. Only roller-milled flour is bleached. The bleaching is carried on in electrical machines in which air is made to pass over sparking electrodes, with the resulting formation of ozone and nitrogen peroxide. It is only the latter gas, however, that has any bleaching action on flour. There appears to be no advantage to the consumer in the bleaching of flour, except that he gets a whiter loaf; but the process is advantageous to the miller, as a dark-coloured flour when whitened by bleaching fetches a higher price than it otherwise would. The most important chemical change produced by bleaching is the formation of nitrites from the nitrogen peroxide, but these are seldom present in greater amount than from 0·5 to 1 or 2 parts per million. There is no evidence that this is harmful to human beings. With the higher degrees of bleaching Monier-Williams shows that there is some increase in the soluble proteins and carbo-hydrates of the flour, and the oil becomes oxidized. No diazo-compounds appear to be formed.

Phosphates and other substances (added as "improvers") increase the water-absorbing capacity of the flour, and are said to improve its baking qualities.

Bread is made by mixing water, yeast, and a little salt with wheat flour until a consistent dough is formed, which is allowed to rise before a hot fire and then placed in a baking oven. By the action of the yeast at a suitable temperature, some of the starch is changed into sugar, and the sugar splits up into alcohol

and carbonic acid gas. The coherent nature of the gluten prevents the escape of the carbonic acid gas, which forms for itself little cells in the substance of the loaf, and causes the spongy structure characteristic of well-made bread The alcohol escapes into the air. It is important not to let the fermentative process go too far, or lactic and butyric acids may be formed, which cause the bread to be sour. Alum has the property of arresting

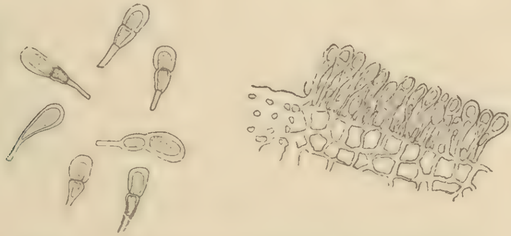


FIG. 67.—PUCCINIA GRAMINIS (× about 200).

this change, and of imparting a fine white colour to bread. Hence its frequent use in baking powders. The loaf when "risen" is put into the oven and baked. It appears, from experiments conducted by Drs. Waldo and Walsh, that the temperature of the interior of a loaf in a baker's oven is not sufficiently high to destroy all microbes. The process of baking, therefore, does not sterilize the loaf.

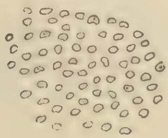


FIG. 68.—SMUT SPORES: UREDO SEGETUM (× about 200).

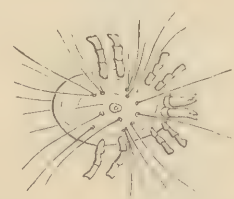


FIG. 69.—ACARUS FARINÆ (× about 40).

Aerated bread is now extensively used. In this system CO_2 gas is prepared and forced through the dough under pressure. Its great advantage lies in the fact that there is no fermentation as in ordinary bread-making, and no danger of sourness and acidity being produced. There is besides no loss of starch, and no yeast is left in the bread to cause fermentative changes in the stomach, giving rise to acidity, heartburn, and flatulence. On the other hand, the yeast fermentation is supposed to render

the bread more easily attacked by the digestive juices—in other words, more digestible. Baking powders are occasionally used to disengage CO_2 gas, and cause dough to rise. They usually consist of sodium carbonate and some acid such as citric or tartaric, mixed with rice flour. Baking powders are also sold

FIG. 70.—VIBRIONES TRITICI (× about 40).

FIG. 71.—WEEVIL (× about 40).

in which the acid constituent is furnished by acid phosphate, and in other cases by the sulphuric acid contained in some form of alum salt. The calcium acid phosphate commonly employed often contains a large proportion of calcium sulphate, and Hamill

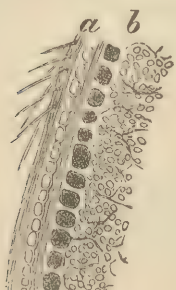


FIG. 72. — SECTION OF WHEAT GRAIN: OUTER COAT.
a, Girdle cells; *b*, cerealin cells (× about 50).

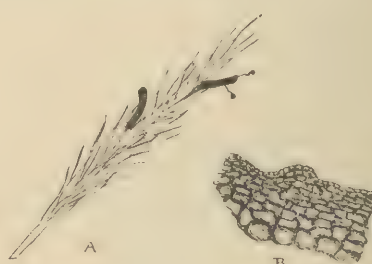


FIG. 73.—*A*, EAR OF RYE WITH ERGOT —THE LATTER SHOWN AS GERMINATING AND PRODUCING "CLAVICEPS PURPUREA"; *B*, A SLICE OF ERGOT (× about 250).

recommends that the impurity should not be allowed to exceed 10 per cent.

Under the microscope wheat flour is seen to consist of round or oval starch grains, of very various sizes. The smallest are mere points, whilst the larger ones may reach to $\frac{1}{1000}$ inch in diameter or more. Intermediate sizes are very often absent.

The hilum and concentric lines of the starch grains are barely visible, if at all. Portions of the outer envelopes of the wheat grain may be detected in the coarser and more branny flours.

Wheat grains are subject to attack by certain parasites, viz. (figs. 67 to 71), "smut" (*Uredo segetum*) and "bunt" (*Uredo fœtida*), the latter being the commonest; "rust" or *Puccinia graminis*, which attacks the stem and leaf; and ergot (*Oïdium abortifaciens*) (fig. 73), which, however, is more often a disease of rye. Amongst the numerous animal destroyers of wheat are: *Vibrio tritici*, or ear cockle, which destroys the grain and fills it with a cotton-like substance; *Acarus farinæ;* and the weevil, or *Calandra granaria* (fig. 71), a little insect—visible to the naked eye—which eats the core out of the grain, leaving only the shell. *Lolium temulentum*, or darnel seeds, occasionally find their way into flour, and have given rise to symptoms of narcotic poisoning among some of those who consumed the bread made from such flour.

Other fungi may likewise be recognized by means of the microscope in the flour made from blighted and diseased corn; and flour and bread, when badly stored and allowed to become damp, become the seat of growth of mould and fungi such as *Mucor mucedo*, *Penicillium*, and *Aspergillus* (see pp. 362 and 363). All these growths are apt to produce dyspepsia and diarrhœa, whilst the prolonged consumption of ergoted bread may give rise to the symptoms of ergotism, viz., painful cramps in the limbs and gangrene of the extremities. Ergot may also be detected by the herring-like smell of propylamine which is produced when liquor potassæ is added to ergoted flour.

When wheat is at a low price, adulteration is very little practised. Alumina is normally present to a very slight extent in flour and bread (equivalent to 6 to 10 grains of alum in a 4 pound loaf). When alum is added in any quantity, its presence may be detected by pouring a fresh infusion of logwood, made with distilled water, over the flour or bread. The colour of the logwood changes to a lavender or violet-grey in the presence of alum. There can be little doubt that alumed bread tends to produce dyspepsia and constipation, and it permits of an inferior flour being sold as a good one, but it is now only added in small quantities in certain baking powders.

The adulteration of wheat flour with other grains, such as barley, potato, beans, peas, maize, oats, rye, and rice, is

now but little resorted to, but may be practised as a "war measure."

The nitrogenous substances in these grains have little or no adhesive properties like wheat gluten, so that bread of an inferior quality can only be made from them.

The nutritive values of some of these cereals will be seen from the table below.

	Wheat (winter sown).	Barley.	Oats.	Maize.	Rye.	Rice.
Starch[1]	63·71	63·51	49·78	64·66	61·87	77·66
Nitrogenous matter (*i.e.*, albumin, cerealin, etc.) ..	15·53	11·46	14·67	14·27	14·87	9·34
Cellulose	3·03	7·28	13·53	1·86	3·23	Traces
Sugar[2]	2·57	1·34	2·36	1·94	4·30	0·38
Fat	1·48	1·03	5·14	3·58	1·43	0·19
Mineral matter ..	1·60	2·32	2·66	1·35	1·85	0·28
Moisture	12·08	13·06	11·86	12·34	12·45	12·15
Total	100·00	100·00	100·00	100·00	100·00	100·00

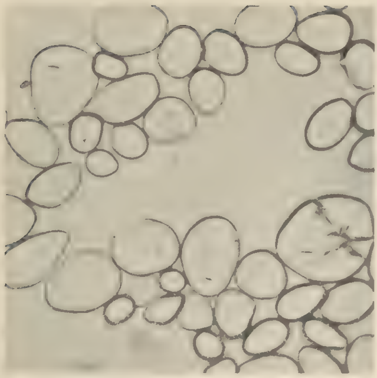
It will be seen that barley is—compared with wheat—poor in nitrogenous matter and sugar, but rich in cellulose and mineral matter; that oats are exceptionally rich in cellulose and fat, possess a high amount of mineral matter, but are relatively poor in starch; that maize possesses a high amount of fat, but the cellulose is low; that rye is exceptionally rich in sugar, and in other respects closely approximates to wheat; and that rice is rich in starch, but poor in everything else.

Barleymeal, oatmeal, peas, lentils, and maize or Indian corn, are all most nutritious and fattening, and very cheap They are easily made into most nourishing porridges, soups, or puddings, with a little milk, and form very valuable—though greatly neglected—foods for people of small incomes. Starchy foods must be carefully cooked to render them digestible. By boiling or otherwise cooking, the cellulose coats of the starch granule are ruptured, and the saliva and pancreatic juice then have

[1] The starch includes from 1 to 1·5 per cent. of dextrine, and together with cellulose and sugar, comprises the carbo-hydrates of the cereals.

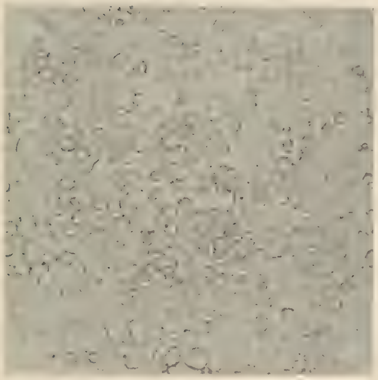
[2] The saccharine body is allied to cane-sugar in its reactions.

PLATE I

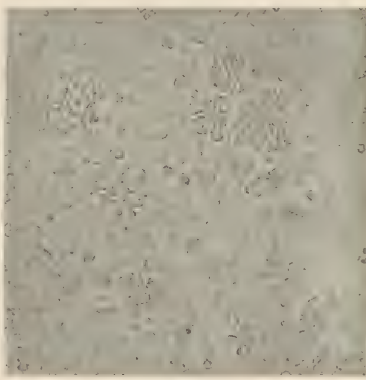


ARROWROOT

POTATO



OAT



RICE

PEA

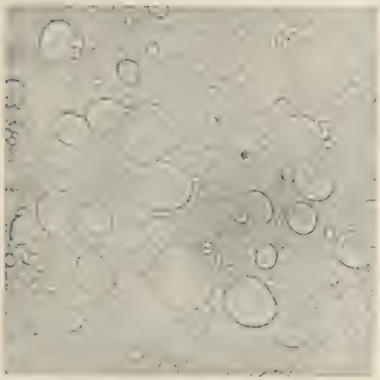
BEAN

STARCH GRANULES. (× 250.)

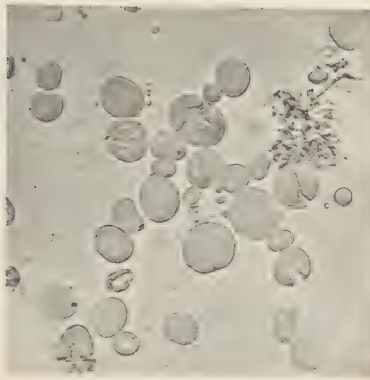
E. C. Bousfield, photo.

To face page 385.

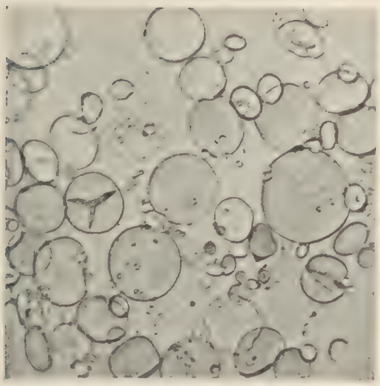
PLATE II



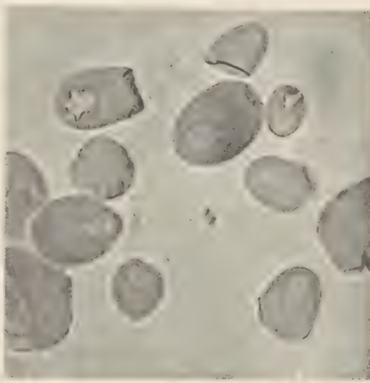
WHEAT



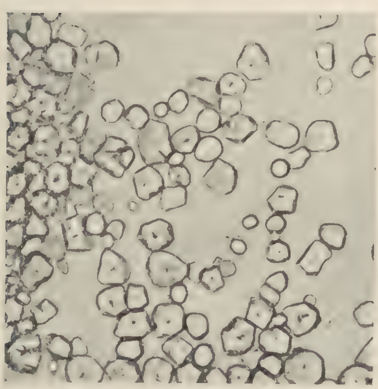
BARLEY



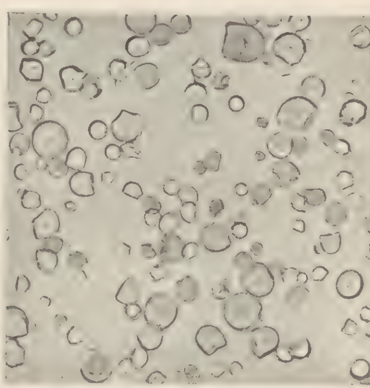
RYE



SAGO



MAIZE



TAPIOCA

STARCH GRANULES (× 250.)

E. C. Bousfield, photo.

To face page 385.

ready access to the granulose — the inner contents of the granule.

Barley.—The starch grains are almost indistinguishable from wheat. Barley is very nutritious, and the ash is rich in iron and phosphates.

Rye.—The starch grains are like those of wheat, but many have a peculiar rayed hilum. Rye can be made into bread, which is very acid and dark coloured, and liable to produce diarrhœa in those unaccustomed to it.

Oatmeal.—The starch grains are small and angular, and tend to cohere into rounded masses. It is most nutritious and somewhat laxative. When badly prepared, oatmeal may contain hairs and husks, which are liable to form intestinal concretions.

Maize.—The starch grains are small, compressed, and faceted. Pellagra, *Elephantiasis Italica*, is a constitutional disease operating destructively on the integument. It is most prevalent among those living under the adverse conditions of dirt and poverty so rife in Italy. That the consumption of diseased or damaged maize, to the exclusion of other diet, is probably the main factor in producing epidemics of the disease is supported by the circumstance that in the Lombardo-Venetian territory, where this is the chief food of the agricultural labourer, the disease is most in evidence, and also by the fact that pellagra-like symptoms have been produced by feeding lower animals with diseased maize. Briefly put, it would appear that the diets of pellagrins are on occasion deficient in three respects. The diets are of low protein content and do not yield a mixture of amino-acids favourable for transformation into body tissues. They lack a sufficient amount of the unidentified dietary essential, fat-soluble A. They are deficient in certain mineral elements, chiefly calcium. Any one of these deficiencies is sufficient to induce malnutrition in the young or adult. Not everyone, however, on such a poor diet develops the disease, and cases of pellagra occur in people whose diet has been entirely adequate.

Peas and Beans.—Pea starch grains are more or less oval, and many of them have a central longitudinal cleft extending nearly the whole length of the grain. Bean starch cells are somewhat larger and more flattened, and the longitudinal cleft is crossed by transverse fissures. Peas and beans contain a large amount of proteid substance called legumin (hence the name of Leguminosæ applied to this natural order of plant), also sulphur

and phosphorus. They are highly nutritious, but somewhat indigestible, and are apt to give rise to flatus from the formation of sulphuretted hydrogen.

Rice.—The starch grains are very minute, angular, and faceted; in shape like maize starch cells, but very much smaller. Rice is poor in everything but starch, which is, however, extremely digestible when cooked. It has been held to give rise to beri-beri, when polished decorticated rice has been too exclusively used for human food (see Beri-beri, Chapter IX.).

Arrowroot.—There are many different kinds of arrowroot, obtained from various countries. As a rule, the starch grains are oval or pyriform in shape, of large size, and with the hilum as a slight cleft or cross at the larger end of the grain. The concentric lines are very well marked.

Sago and Tapioca.—The starch grains of sago are large, irregular in shape, with ill-defined concentric lines. Those of tapioca resemble sago, but are considerably smaller.

Potato.—The starch grains of potato are very characteristic. Many of them are large and pyriform in shape, the hilum being at the smaller end, and the concentric lines are very well marked. Potatoes are very deficient in proteids and fats, but the starch is most digestible when properly cooked; and they are valuable antiscorbutics. They contain large quantities of the salts of the vegetable acids—malates, tartrates, and citrates. The juice of the potato is acid. Potatoes are better cooked by steaming in their skins than by boiling when peeled; for by the first method there is no loss of the salts to the water used for boiling, as occurs in the second method.

In the case of all vegetables, and, in fact, in all cooking processes, soft water is far better than hard water.

The consumption of potatoes has been responsible for the occurrence of symptoms of solanin poisoning.

BEVERAGES.

Coffee.

Coffee berries contain fat, legumin, sugar, dextrine, vegetable acids, and mineral salts; also an aromatic oil, an alkaloid—caffein (about 1·0 per cent.)—and an astringent—caffeo-tannic acid. When the berry is roasted, it swells from the formation of gases, the sugar is changed into caramel, and the aroma is

developed. The roasted coffee is made into a beverage by infusion with nearly boiling water. If the water is used at a boiling temperature some of the aroma is lost.

The coffee infusion acts as a stimulus to the nervous system; it increases the frequency of the heart's action, the urinary excretion, and the action of the skin, and is said to increase the carbonic acid given off from the lungs. It has considerable effect in removing the sensation of fatigue. It is valuable as a beverage for men undergoing exertion both in hot and cold climates, from its stimulant and invigorating qualities. The heat of the infusion is useful in cold climates, whilst the increased action of the skin produces a cooling effect in hot climates.

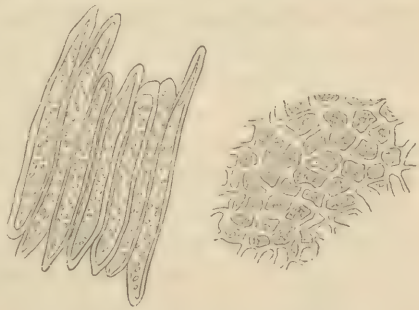


FIG. 74.—COFFEE: CELLS OF TESTA AND CELLULAR STRUCTURE (× about 200).

The principal adulterant of coffee is chicory. Under the microscope, diligent search should be made for the long oval cells of the testa of the berry, with their irregular cross-markings (fig. 74); and fragments of the internal structure of the berry may be seen, consisting of an irregular network of fibres forming a cellular structure, in which are contained dark angular masses and oil globules. All these structures are better seen before the berry is roasted and ground. Chicory is revealed by the presence of fragments of much coarser areolar tissue, and by the long dotted ducts, which are quite characteristic (fig. 75).

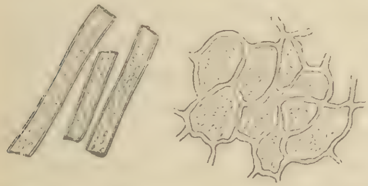


FIG. 75.—CHICORY: DOTTED DUCTS AND CELLULAR STRUCTURE (× about 200).

Roasted coffee floats for a considerable time in water, owing to the gases that are developed in roasting, and to the quantity of fat it contains; whilst roasted chicory rapidly sinks. Unlike coffee, chicory contains no aromatic oil nor caffein, but it has much sugar in its composition. When mixed with coffee it serves to sweeten it, and causes a darker coloured infusion than pure coffee; but the stimulating effect of the mixture is less

than that of pure coffee. Rare adulterants of coffee are other starches (such as potato and sago), and caramel or burnt sugar.

Tea.

Dried tea leaves contain albumin, extractives, dextrine, and mineral salts, also tannin (about 6 to 12 per cent.), an aromatic oil, and an alkaloid—thein (2 to 3 per cent.). Green tea contains more tannic acid and ethereal oils than black tea, and is prepared from younger leaves, but the thein appears to be generally less in amount. The difference between black and green teas is entirely due to their mode of preparation; they are both derived from the same plant. Formerly tea was exported almost exclusively from China, but now Indian and Ceylon teas have come largely into the market.

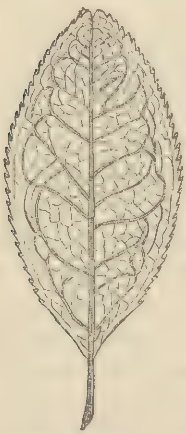


Fig. 76.—Tea Leaf.

Tea should be made with boiling water, but it should not be allowed to stand for more than five minutes, the infusion being then poured into another vessel. If this is not done, so much tannin is extracted as to cause the infusion to be bitter and astringent, and most unwholesome. If soft water is used, a smaller quantity of tea is necessary than with hard water, as the soft water extracts more from the leaves than hard. Dextrine, glucose, tannin, thein, the volatile oil, and a small quantity of the albumin pass into the infusion. Tea should not be taken with or shortly after meals, as the tannin tends to coagulate the albumins of the food undergoing the process of digestion.

The action of tea on the system is similar to that of coffee. It is, therefore, valuable as a nervous stimulant and restorative in fatigued conditions of the body. The abuse of tea leads to weakened digestion, constipation from the astringent properties of the tannin, and nervous depression leading to insomnia and trembling—the effects of the volatile oil and thein.

The structure of the tea leaf is characteristic, and is best seen when the leaf is young and green. It is oval in shape (fig. 76), with a serrated border, each serration being spine mounted, and

the serrations terminating a little before the point of attachment of the stalk; the primary veins run out alternately from the midrib, and turn towards the point of the leaf, but without reaching the border, the venation being looped; the apex of the leaf is notched. Adulteration with foreign leaves is now little practised; but used leaves may be dried, mixed with gum and rolled, and sold as sound tea. Green tea used to be coloured or faced with indigo, Prussian blue, and other mineral substances.

Cocoa.

Cocoa is a food as well as a beverage, and is much less astringent than tea or coffee. Cocoa nibs contain nearly 50 per cent. of oil (cocoa butter), proteins about 15 per cent., and theobromin—allied to thein and caffein—1·0 to 1·7 per cent. The ash is rich in phosphate of potash. For people of weak digestion, some of the fat of the cocoa should be removed by heat and pressure.

Cocoa is generally adulterated with sugar and the cheaper starches, in order to disguise the large amount of fat and to render it more palatable. The starch grains of cocoa are very small, and are often seen massed in the intercellular spaces of the structure of the nib.

Chocolate is cocoa from which much of the fat has been removed; the paste remaining is then mixed up with a considerable quantity of sugar and flavouring substances. It is liable to be attacked by the larvæ of the chocolate moth, *Ephestia elutella*. Inferior chocolate may be very deficient in cocoa.

Chocolate may be adulterated with cocoa-shell, foreign starches, or foreign fats.

Mineral Waters.

These are either derived from natural springs, the water of which contains gases (usually CO_2) or mineral salts in solution (salts of potassium, sodium, magnesium or lithium), or they are manufactured by impregnating ordinary river, spring, or well water with CO_2 gas, and dissolving in it small quantities of the mineral salts usually found in natural waters. Both kinds of water have come very largely into use in recent years. Besides the stimulant effect upon the digestive organs of the contained CO_2 and the dietetic or aperient value of the mineral salts, these waters serve a useful purpose in providing a pure beverage for

consumption in cases where there may be hesitation to drink the ordinary water provided for domestic purposes, on the ground of its impurity. Care should be taken, however, to choose a mineral water which does not contain an excess of common salt, producing thirst, or an excess of alkaline salts, which act as depressants on the nervous system. Travellers both at home and abroad usually show a wise discretion in their preference for mineral waters to the ordinary water of the establishments in which they are staying or seeking refreshment. Too much reliance, however, should not be placed on the purity of all artificial waters, as in more than one instance it has come to our knowledge that certain manufacturers have obtained their waters from grossly polluted sources.

There is one other danger in the use of the artificially aerated waters that requires mention. They often exhibit traces, and sometimes very decided traces, of lead. This metal is dissolved from lead pipes or leaden apparatus used in the manufacture of the CO_2, and the water charged with this gas holds the lead in solution. Another possible source of the metal is the silicate of lead which enters into the composition of the glass bottles in which such waters are stored. The habitual use of these waters containing traces of lead might in time lead to the development of symptoms of lead poisoning, the source of which would in all probability be overlooked.

Fermented Liquors.

A solution of grape sugar when subjected to the action of the yeast plant (*Saccharomyces cerevisiæ*) at a temperature of from 20° C. to 30° C., is mainly split up into alcohol and carbonic acid.

$$C_6H_{12}O_6 = 2C_2H_6O + 2CO_2.$$

The yeast plant is composed of minute organized cells, oval in shape, and with granular protoplasm (fig. 77). In the presence of saccharine fluids at a suitable temperature, the cells undergo enormous multiplication by the process of budding, and the alcoholic fermentation ensues. Under the microscope, the cells which are budding may be seen as one large cell united to one or two smaller cells, end to end; or groups of several budding cells are attached together. The CO_2 escapes as gas fro i the fermenting liquor, whilst the alcohol remains dissolved in the solution.

The fermented drinks may be considered under the heads of spirits, wines, and beers.

Spirits.—Brandy is spirit derived from the grape. It contains about 50 per cent. of alcohol, the remainder of the liquor being water, in which are held various secondary products, including acids, aldehydes, ethers, furfural and higher alcohols. Its specific gravity is generally from 0·930 to 0·940 at 62° F. Rum is distilled from fermented molasses.

Whisky is made by distillation of malted grain. When new, it contains amylic alcohol or fusel oil, a substance which, when present in any quantity, produces rapid intoxication, followed by intense headache and depression. The percentage of alcohol in whisky is much the same as in brandy. Gin is weaker in alcohol; it contains oil of juniper, and is sweetened with various aromatic substances. Absinthe is a liqueur flavoured with various essential oils, and contains oil of wormwood, a powerful poison to the nervous system.

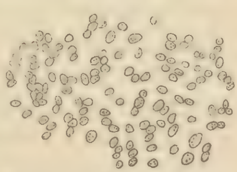


FIG. 77.—TORULA CEREVISIÆ: YEAST PLANT (× about 200).

Brandy, as sold commercially, is now very largely blended with varying amounts of spirit obtained from the distillation of corn grain spirit, etc. The dietetic and medicinal values of these sophisticated articles are probably inferior to those of the genuine wine spirit; and recent legal decisions show that the sale of blended spirits, when brandy is demanded, is an infringement of the Sale of Food and Drugs Act. Analysis differentiates between a pot still and a patent still spirit, because the secondary products are practically absent in the latter owing to the spirit being more highly rectified by means of the patent or fractionating still. A therapeutic value has been ascribed to these secondary products, but the evidence is not conclusive.

The secondary products in whisky are small in amount; it contains relatively more higher alcohols but less compound ethers than brandy; it further contains traces of empyreumatic or tarry substances derived from the malting process.

Wines.—What are known as the lighter wines—the Bordeaux, Burgundies, Rhine wines, Champagnes, and Moselles—contain usually less than 10 to 15 per cent. of alcohol by volume. The stronger wines—port, sherry, and madeira—contain from 15 to 25 per cent. of spirit. Besides alcohol, wines contain various

aromatic compound ethers which impart the bouquet, albuminous and colouring matters, sugar, free organic acids, and the acid salts of the vegetable acid series, including tannic acid (which is largest in amount in new port wines) and mineral salts, chiefly those of potassium.

Wines are manufactured from the fermented juice of the grape. Cheap wines are largely made from other fruits, and even grape juice wine is subject to various fortifications and adulterations to fit it for different markets. Home-made wines and cider are occasionally manufactured or stored in earthenware vessels, coated inside with a litharge glaze, which readily gives up large quantities of lead to such acid liquids, and may be thus productive of lead poisoning. If earthenware vessels are used, they should be coated with a hard salt glaze. When wine is kept long in cask or bottle, there is a deposit of the colouring matter and tannic acid, and some of the sugar disappears. If air is not absolutely excluded, the acetous fermentation is liable to be set up from the entrance of the ferment (*Mycoderma aceti*), which transforms alcohol into acetic acid (C_2H_6O becomes $C_2H_4O_2$), and the wine is soured. The more common adulterants used are sugar, various ethers, logwood and other colouring agents, alum, and sulphate of lime. The latter improves the colour of cheap wines, and the addition is known as the "plastering" of wine. The practice is injurious, and by giving rise to the formation of potassium sulphate it induces a purgative effect upon consumers.

Beers.—These beverages were formerly made from malt and hops only; now they can be legally made from starch and sugar and various vegetable bitters.

Pure beer is the fermented liquor obtained from the germinating grain of barley. The grains are made to partially germinate by being first moistened and then kept warm until they begin to sprout. A small quantity of the ferment "diastase" is thus produced. Further germination is then prevented by heating the barley in kilns and thus converting it into "malt." The malt is next subjected to "mashing" by mixing with water at 180° F. and well crushing and stirring for about two hours. During this process the diastase acts upon the starch, and largely converts it into the sugar—"maltose," which is easily fermentable. After clarifying, the infusion is boiled with hops, and then the cooled liquor or "wort" is transferred to vats to ferment (yeast being added). When this alcoholic fermentation has

proceeded far enough the yeast is removed and the beer is run into casks.

In recent years glucoses and invert sugars have been largely substituted for the malt, and these sugars have been obtained from rice and other starches which are not fermentable until they are converted into "invert sugar" by the action of dilute sulphuric acid. The commercial sulphuric acid is liable to contain a considerable amount of arsenic (derived from the iron pyrites used in its manufacture); and this circumstance was responsible for a considerable outbreak of arsenical poisoning among beer consumers, chiefly in the north-western part of England, in the winter of 1900-1901. Amounts of arsenic varying from $\frac{1}{500}$ to 1 grain per gallon of beer were found by analysis, and some invert sugars were found to contain arsenic equivalent to 2·04 grains of arsenious oxide per pound.

It may be stated that traces of arsenic have been found in jams, sweets, lemonade, liqueurs, sugar, and treacle—all now largely manufactured from glucose—and also in several chemical substances—such as sulphate of soda, phosphate of soda, carbonate of soda and potash, caustic soda, sulphurous acid, sulphites, borax, oxide of iron (used for colouring confectionery), etc. It has also been pointed out that the coke used for kilning the barley gives off traces of arsenic when burned.

The percentage of alcohol in beer varies from 3 per cent. in the lighter to 6 or 7 per cent. in the heavy beers. There are also contained in beer, malt extract, 4 to 15 per cent., free organic acids, traces of albuminous matters, and salts.

Considered as articles of diet, wine and beer will produce effects which may be partly ascribed to the action of alcohol on the system, and partly to the other constituents of which they are composed.

Leaving out of consideration for the moment the effects of the alcohol, it will be seen that wine and beer possess some of the properties of a food. They contain sugar and starchy matters, mineral salts rich in potash and phosphates, and a considerable amount of the vegetable acids and their salts which may be valuable as antiscorbutics. The compound aromatic ethers in wine may also act as aids to digestion, by promoting the flow of the pancreatic and intestinal juices; and the bitters of beer act as stomachic tonics and appetizers.

Herb and botanic beer and ginger beer, which are sold as

"non-alcoholic" beverages, often contain proof-spirit in excess of the limit of 2 per cent. A few of the many samples of ginger beer analyzed at the Government laboratories during the years 1905, 1906, and 1907 contained 6 per cent. of proof-spirit—one sample containing 9·5 per cent.; a sample of herb beer contained 10·5 per cent. of proof-spirit, and one of dandelion stout 12·3 per cent.

Effects of Alcohol.

Alcohol when taken into the body is rapidly absorbed unchanged into the blood. Taken in excess, it speedily commences to pass out of the body in an unaltered condition. The principal channel of elimination is the lungs and breath, but small portions are got rid of by the skin, the urine, and the bowels. The greater portion, however, of the alcohol (98 per cent.) is destroyed in the body. In fact, when taken in small (not excessive) quantities, alcohol acts as a food, supplying heat and energy by its oxidation in a similar manner to the fats and carbo-hydrates.

After full doses of alcohol given to a healthy man or animal, the following effects have been noted: 1. The vessels of the stomach are dilated, and the flow of gastric juice augmented. 2. The force and frequency of action of the heart are increased. 3. There is partial paralysis of the vaso-motor nerves to the superficial vessels, which dilate, causing flushing of the skin of the face and other parts. 4. The brain is partially anæsthetized; the rapidity of external impressions, the power of concentrated thought, and the discrimination of the senses, are all lessened, as is also sustained voluntary muscular power. 5. The temperature of the body is slightly depressed,; but although there may be a decreased elimination of CO_2 by the lungs, there is no delay or diminution in the metamorphosis of tissue, for the excretion of urea in the urine is not affected. 6. The acidity and water of the urine are somewhat increased.

The long continued immoderate use of alcohol leads to degenerative changes, primarily in the stomach and liver, and at a later period in the kidneys, lungs, brain and bloodvessels. The degeneration is characterized by increased growth of interstitial fibrous tissue, which in course of time shrinks and causes atrophy of gland cells and loss of function. Chronic catarrh and cirrhosis of the stomach with cirrhosis of the liver, followed by dropsy

and hæmorrhage, are the well-recognized results of alcoholic intemperance.

The effect of such intemperance in shortening life is now universally recognized. Statistics bear overwhelming evidence on this point. It may be stated generally that the mortality of the intemperate is from four to five times greater than that of the strictly temperate of the same age and in the same class of life. When the mortality of all occupied males in 1890-92, at ages ranging from twenty-five to sixty-five years, from alcoholism and diseases of the liver, is expressed as 100, and the mortality in each separate industry is expressed as a figure proportional to that standard, the following results are obtained by Dr. Tatham (Supplement to the 55th Report of the Registrar-General):—

Deaths from Alcohol and Diseases of the Liver (1890-92).

All occupied males ..	100	Dock labourer	195
Coachman, cabman ..	153	Chimney sweeper.. ..	200
Costermonger	163	Butcher	228
Coal heaver	165	Brewer	250
Fishmonger	168	Inn servant	420
Musician	168	Inn keeper	733
Hairdresser..	175		

Dr. Tatham points out that the mortality from alcoholism is often registered as due to other causes that are known to be frequently associated with alcoholic excess, and this is often purposely done out of regard to the feelings of relatives. Experience proves that the liver is the organ which, more than any other, is affected prejudicially by intemperance.

Those engaged in the brewing and licensed victualling trades are notably an intemperate class; but, naturally, if the temperate men in these trades could be excluded, the figures indicating special disease of organs would be very much magnified.

Little can be said against the use of beer and wine in strict moderation; but taken habitually in excess, they lead to the storage up of superfluous fat in the tissues, and they interfere with the proper elimination of effete matters; imperfect oxidation leads to an excessive formation of uric acid, and a plethoric and gouty habit is produced, eventually tending to palpable disease. These effects are, doubtless, in part due to the excess of alcohol taken into the system, but not entirely. Lessened metamorphosis has a considerable share in their production.

All evidence points to the fact that alcohol, except in strict moderation, is injurious to men who are exposed to extremes of

climate (great heat and great cold), or who have to undergo great bodily or mental labour. Its effect on the circulation is distinctly injurious to those engaged in hard bodily work, for it causes the heart to do more work without conferring any counterbalancing advantage.

In strictly moderate doses alcohol has not been proved to do any harm; and, taken in the form of beer or wine, many of the inhabitants of our large towns find it a useful aid to digestion and assimilation. But it must be remembered that there are idiosyncrasies as regards alcohol, and that what is harmless to one individual may be injurious to another. For thoroughly healthy people, alcohol in any form presents no advantages, and for children and young people it is decidedly injurious. The comparative immunity enjoyed by drunken persons from the usual effects of accidents is due to the paralysis of those nervous centres through which a shock would be produced in a condition of sobriety.

During the last fifty years the consumption of intoxicating liquors in the United Kingdom has fallen considerably—more especially the consumption of spirits.

The Report of the Departmental Committee, which was appointed to report upon Physical Deterioration, brought out the following facts:—

1. That the abuse of alcoholic stimulants, whether in the form of spirits, wine, or beer, is largely responsible for physical deterioration, and that it leads to disease in most tissues and organs of the body.

2. That alcoholic excess reduces the natural power of resistance to disease possessed by healthy individuals, rendering them especially liable to many inflammatory disorders, causing them to suffer much more severely from any illness they may contract, and making their recovery slow.

3. That intemperance predisposes to consumption.

4. That children of intemperate parents are seriously affected; they frequently suffer from paralysis, epilepsy, and idiocy, which lead, if not to death, to their permanent disablement. From statistics obtained, it was found that the mortality among children of intemperate parents was many times greater than among children of sober parents of the same class.

5. That the increase in lunacy is largely due to intemperance, and that there is also an increase in the number of cases of general paralysis from the same cause.

The Swedish (Gothenburg) system seeks to diminish the abuse of alcoholic stimulants, to acquire public-houses, and to devote the profits accruing from the sale of alcoholic drinks to public

purposes. There is strict local option as to the provision of public-houses, and conditions are imposed upon the sale of wines and spirits, but not of beer.

One of the best restorative drinks is hot milk with a liberal allowance of cane sugar. The cane sugar acts as a tonic to the muscular system. Dry ginger ale is probably the best of the manufactured non-alcoholic beverages. An excellent hot weather drink is barley water or oatmeal water. Butter-milk is both food and drink; it is excellent as a quencher of thirst.

CANNED AND BOTTLED FOODS.

The amount of tinned or canned food-stuffs upon the market is very considerable, and it constitutes an increasing part of the food supply of large communities. The canning of food has the effect of preserving a large amount of material which would not otherwise be available for food, and it is thus a provision which cheapens the cost of living; moreover, for the purposes of our Colonies, of the Army and Navy, or for expeditions to parts of the world where food is scarce, canned food is essential. There is no doubt that when meat preserved in this way has to be consumed for long periods, the consumer suffers less than when salted meat is exclusively eaten; but experience has shown that health cannot be maintained for several months on these canned foods unless a certain amount of fresh animal or vegetable food is introduced into the diet.

In preserved meat the process of canning causes a drying and shrinkage of the raw material, so that 30 ounces of tinned meat represent some 45 ounces of the fresh. It should contain a fair percentage of fat, and the meat juices should not be too much reduced, as is the case in the " hot pickle " process. Potassium nitrate is often employed in corned beef, etc., to preserve the red colour of fresh meat.

It is, of course, of prime importance that the material to be canned should be in a wholesome condition at the time of canning, but it is also very important that the cans in which the material is placed should be of good quality and sound. The coating of the can with tin should be properly done, so that no flaws are perceptible with the magnifying glass, as otherwise the iron beneath will rust through; the tin used for coating should not contain more than 1 per cent. of lead; and " terne-plate," which

consists of 2 parts of tin to one of lead, should be prohibited; the solder employed in the tins should not contain more than 10 per cent. of lead, and should be kept entirely on the outside of the tin; and those tins which are to contain much acid juice (namely, vinegar, plum, and asparagus juice) should be lacquered inside.

The most usual process of canning is briefly as follows:—The food is placed in the tin and the lid is soldered on. The small "blow-hole," which is generally in the centre of the lid, is sealed by solder. The sealed tin is then placed in either a steam retort at 115° C. for from one to two hours, or in a boiling solution of calcium chloride for the same period, or in ordinary boiling water for about four hours. The tin is then removed from the retort or boiling solution, and the solder seal is quickly melted off, by means of a red-hot instrument, when the expanded gases escape; the small blow-hole is again sealed with solder, and the tin and its contents are again placed in the steam retort for another hour. The finished tin has then two concave surfaces and emits a hard sound on percussion.

Should, however, there be any flaw in the tins, or the solder seal be imperfectly applied, or should the heating process be ineffectually performed, then the contents may go bad. In this event, owing to the accumulation of the gases of putrefaction, the tops and bottoms of the tins become quite flat, and later on convex outwards, and the tin when struck gives out a hollow or drum-like sound. It is not difficult, therefore, in the majority of cases, to detect, before opening them, those tins in which the contents are bad. Sometimes, however, "blown" tins have been punctured to allow the accumulated gases to escape, and the small opening has been, subsequent to re-sterilization, closed by solder. The presence of two solder points on a tin might therefore justify a suspicion that this practice had been resorted to, but as a rule the solder upon the original blow-hole would be melted and afterwards renewed.

The two solder points do not necessarily indicate fraud, because it is sometimes found more expeditious and convenient to make a second blow-hole to let out the expanded gases rather than to unseal the original one. Again, what appears to be a second solder point may sometimes be nothing more than a splash of solder accidentally deposited.

Beveridge has shown that the "blowing" of tins is due to

the spores of *Bacillus cadaveris*, which are extremely resistant to heat. These spores take about a fortnight to develop. They may not be destroyed by the so-called sterilization; may remain inert for long periods if the tins are stored at a low temperature; but may develop if the temperature reaches 37° C. or thereabouts. They are non-pathogenic to animals, but decompose the meat, and render it unfit for human consumption.

The bacillus of Gaertner and *Bacillus botulinus* are very rarely (if ever) found in canned foods, unless the cans have been opened and the material exposed to contamination.

These facts explain the circumstance that tins of meat which have passed the makers' tests, and have kept good for months, suddenly become blown and unfit for use. It was recognized that this occurrence was not due to injury of the tin through rust and entrance of air organisms; for if so, the gas produced by putrefaction would have escaped, and no blowing would have resulted.

The recommendation is accordingly made that the temperature of sterilization should be raised to 120° C. (240° F.), and that this temperature should be maintained for one hour.

The bulging of tins results from:—(1) The formation of gas by putrefaction of the contents of the tin; (2) the displacement of the contents from rough handling and rough usage so as to make the ends bulge; (3) the freezing of the contents of tins of liquid or semi-liquid foods, as when kept in cold storage, this sometimes making the ends bulge for the same reason that frost bursts water-pipes. It may be stated that the bulging of tins of condensed milk is not necessarily due to any of the above causes; it may be produced by gas formed by electrolytic action between the metal of which the cans are composed and the acids generated by the growth of bacteria in the milk before the latter was condensed. The vinegar in which certain vegetables are conserved may produce gases in the same way.

The dangers to health in the consumption of tinned or canned foods arise (1) from changes in the food itself (which may either be of a definite putrefactive nature or due to the development of non-putrefactive ptomaines or toxins); (2) from the use of antiseptics; (3) from the addition of colouring agents; or (4) from impurities yielded by the tins. Putrefactive changes cause the generation of gas within the tin, which leads to a blowing or bulging, and when the bulged end is tapped the sound is muffled

or drum-like. The most delicate means of detecting "blowing" is to place a drop of water on the top of the tin and then puncture the tin through the water. The water is sucked inwards as a rule in a tin with sound contents; but a few fine bubbles escape through the water if the tin is slightly blown. On opening the tin a discoloration of the inside of the tin is often observable; the contents are often discoloured and soft (fish, for instance, is often yellowish, soft and friable); and, lastly, the odour of putrefaction may be perceptible.

Viry states that putrefactive changes in canned foods may take place without the formation of any gas; and it is certain that the evil consequences which have sometimes been traced to the consumption of canned food were due to ptomaines which were formed in partly decomposed material prior to canning.

The development of ptomaines and toxins in food, and the use of colouring agents and antiseptics, are dealt with elsewhere. But a word must be said with reference to the impurities yielded by the tins. Metallic tin may be dissolved by acids or by oil (as in the case of canned pieces of pine, lobster, condensed milk, and sardines); and this metal is the most frequent metallic impurity found in the juices of preserved food, especially of fruit and vegetables, and it should never be allowed to exceed 2 grains per pound of the material. Lead may be dissolved from the solder, or from the varnishes and enamels which have sometimes been used in connection with the tins. It is most important, therefore, that any solder used should be beyond the possibility of contact with the tinned material. In the punched out or moulded can, which represents a great improvement in manufacture, there is only one joint—namely, that between the lid and the body—and this is soldered in such a way as to prevent the possibility of the solder appearing on the inside of the can. It is, moreover, possible by taking a moulded jointless body to firmly clamp the folded edges of the lid and body in a special machine, so that no solder whatever is employed. In some tins a solder trap is used, this being a small cup-shaped piece of tin attached immediately under the vent hole. Glass containers, sealed by air-tight metal caps with rubber washers, are also used, the heat employed in the sterilization of the contents being generally lower than in the case of canned food in order to avoid breakages. Very rarely have traces of arsenic, copper, or zinc been obtained from the juices of preserved foods. In cases

where the tin is attacked by the contained juices, etc., a slaty-blue discoloration is often to be seen.

In conclusion some advice may be offered with reference to the examination and selection of tinned articles. It is desirable to avoid cheap brands, and more especially those which do not bear the name of the maker. A very good idea of the nature of the contents can generally be obtained from an examination of the tins. Poor quality tins commonly contain poor quality material. Of all tinned articles of food, preserved fruits are the most likely to contain metallic impurities; it is well, therefore, only to purchase these when they are bottled. Furthermore, it is very desirable that the contents of the can should be eaten during the day on which it is opened, for there have been recorded instances where those who have eaten the material fresh from the can have escaped, whilst others, partaking of the same material the next day, have suffered from poisoning.

Kenwood and Dove found, as the result of much experimentation, that no chemical test is of much value as an indication of definite decomposition changes before the stage is reached when such changes are equally apparent in the changed physical characters of the material. It was found that a careful examination of the article (always aided by comparing the contents of an obviously sound tin with those of a suspected tin) will generally serve to detect the following physical signs of early decomposition changes, and that such changes are no better indicated by difficult and tedious chemical and physical tests:—

1. *Odour.*—This is more or less changed. The odour would generally be described as one of "staleness"; but, however it is defined, the observer is generally able to appreciate some change. It is well to place any questionable material in a clean, odourless bottle, filled up to the neck with a little strong solution of caustic potash, stoppered with a ground-glass stopper, and placed in the hot incubator for an hour. A control of obviously fresh material is similarly dealt with. At the end of the hour any faint difference in odour generally becomes quite apparent. An offensive odour is generally a sign of very advanced decomposition.

2. *Firmness or Resistance to Pressure.*—Often a fairly early sign of decomposition is an appreciable loss of resistance when some of the article is pressed and broken up between the fingers and thumb. The article is slightly softer and more friable, and the contents of a tin are generally more easily turned out.

3. *Colour.*—A fading or change of a natural colour is another useful sign of decomposition, when it is associated with changes 1 and 2. When the colour changes, it generally turns to a brownish

tint. While the solid matter may show no such changes, any liquid matter present may do so, in which case there may be an increased opacity. The tin coating may also be slightly discoloured in places.

It is suggested that the whole of a consignment should be examined for blown tins, and that when blown tins are found, from 5 to 20 per cent. of a portion of it (say, two cases of four dozen) should be opened. Whether 5, 10, or 20 per cent. of a portion of a consignment are opened, should depend upon the number of blown tins discovered. Canned food in poor tins, and not carrying the name and address of the firm who put it upon the market, calls for the most complete inspection. When there are acid juices or oily liquids in the canned goods examined, it is desirable to collect a little of this liquid and to test it qualitatively and (if necessary) quantitatively for tin.

Each can of preserved meat and fish should carry a warning notice that the contents should always be consumed on the day of opening; for this class of canned material appears to be peculiarly favourable to bacterial invasion, and therefore to the development of toxins; and probably in most of the recorded cases of "food poisoning" from canned goods these harmful products are developed after and not before the cans are opened.

FOOD POISONING.

There is no doubt that flesh in a very early stage of decomposition disagrees with many persons; and abundant evidence is not lacking that when an advanced state of putrefaction has been reached, violent gastro-intestinal irritation, followed by diarrhœa, vomiting, and toxic symptoms, may be induced.

Recorded cases of grave and fatal *food poisoning* have been very numerous, and minor disturbances of the gastro-intestinal tract are probably often due to small doses of poisons produced by bacteria. Often the offending substance appears, to all physical tests, to be quite good and wholesome; but the meat or jelly formed is sometimes observed to be softer and moister, and a slight peculiar odour has been noted. The poisonous food has most commonly been brawn, sausages, ham, pork, veal pie, rabbit pie, potted shrimps, tinned salmon, mackerel, mussels, and oysters; but many other varieties of food have been incriminated, such as cheese, ice-cream, canned goods, potatoes, etc. There is a strange absence of recorded instances where the flesh of sheep has been the offending food; but this is seldom used in the preparation of made foods.

For "meat poisoning" see pp. 341 and 342.

Cheese, milk, cream, butter, and ice-creams, etc., may all rarely contain *tyrotoxicon*, which develops under those circumstances most conducive to fermentative changes generally—viz., warmth and moisture, impure and confined air, and deficient light. It is a diazo-benzene-butyrate, and is found to occur under conditions of improper storage in the various food articles above mentioned; and when the ingestion of any of these articles has given rise to serious consequences, then a search should be instituted for this most powerful poison. The symptoms it creates commonly pass off within a few hours, but occasionally serious consequences have arisen, such as the development of symptoms akin to atropine poisoning, which may be followed by fatal collapse. The physical characters of the article are not necessarily altered in any way, but acidity is always marked, and where this is normally present (as in cheese) it is invariably increased.

Vanilla flavouring in sauces or ice-cream has often given rise, within two hours, to vomiting, tenesmus, diarrhœa, and signs of collapse. The explanation appears to be that the vanillin, by its reducing action, favours the growth of anaerobic bacteria, the vanilla itself being harmless.

Potatoes may give rise to similar symptoms of poisoning, which are said to be due in some cases to a considerable increase of the trace of the poisonous substance "*solanin*" to be found in normal potatoes, but generally to bacterial decomposition by proteus bacilli (Dieudonné). It has been recommended that in order to guard against solanin poisoning, the peel and any sprouts should always be thoroughly removed.

The alkaloidal glucoside "solanin" decomposes in the human body into glucose and the alkaloid "solanidine," the poisonous and fatal effects of which have often been recorded.

Edible and Poisonous Fungi.—With a view to enable residents in the country to distinguish between the poisonous and edible kinds of fungi, and to utilize to a greater extent those varieties which are useful as food, the Board of Agriculture and Fisheries has published a small book of illustrations of those species which are more commonly found in Great Britain, together with brief descriptions of them. It is pointed out in this publication that, contrary to popular belief, the poisonous kinds of fungi are comparatively few in number, while there are, on the other hand,

some fifty species of edible fungi which may safely be eaten. In order to recognize with certainty these different kinds, it is necessary to know those special features possessed by each species which separate it from all others. The rule-of-thumb signs for discriminating between edible and poisonous fungi are valueless, and no reliance should be placed on the presence of a skin that is readily peeled off as an indication of an edible fungus, or on the statements that a silver spoon placed in contact with poisonous kinds becomes tarnished, and that all fungi growing on wood are poisonous.

In England and France most of the cases of fungus poisoning which have been reported are due to *Amanita phalloides*. Muscarin is the toxin to which mushroom poisoning has been commonly ascribed, but the poison of this fungus is probably a toxalbumin. *Amanita phalloides* is white beneath the cap, with a yellowish-white or greenish-white, shining top; and the stem, which is white and smooth, is bulbous, and is clothed at its upper part with an expanded pendant ring. It usually occurs in woods, and it rarely, if ever, grows far away from trees, having a preference to the proximity of the oak variety of tree. The fungus peels almost as well as the common mushroom. Another less common offender is *Lactaria torminosa*.

CHEMICAL PRESERVATIVES AND COLOURING AGENTS ADDED TO FOOD.

The employment of agents, termed antiseptics, which will prevent the development of micro-organisms in food, is now prohibited in milk; but it is extensively practised in connection with other foods. The antiseptics most commonly employed in different kinds of food are: Borax and boracic acid, salicylates, benzoates, formic aldehyde (used as "formalin," a 40 per cent. solution of formic aldehyde), sodium chloride, and vinegar; but saltpetre, chloride of ammonium, sulphate of calcium, alum, spirits of wine, sulphurous acid, and bisulphate of lime, have all been employed.

The preservatives to be specially sought for are: In meats (hams, bacon, sausage, oysters, shrimps, etc.)—boric acid and borax, salicylic acid, and sulphites. Boric acid and borax are preferred because they help to preserve the natural colour better than common salt, etc. In milk products—formic aldehyde, boric acid and borax, and occasionally salicylic acid; often a

mixture of boric acid and borax is employed (such a mixture is sold as "Glacialin"). In jams, jellies, mincemeat, and table delicacies—benzoic acid and salicylic acid or their salts, and occasionally boric acid. In cider and fruit juices—salicylic acid and sulphites. In fermented beverages—salicylic acid, sulphites, fluorides, silico-fluorides, and boro-fluorides. Saccharin may be present in beers, wines, and sweetened articles.

There is no doubt that the unrestricted use of these agents should be condemned; for although in the case of those most commonly employed their use has not been *proved* to cause any direct harm to consumers, it is a reasonable belief that the ignorant employment, even of such a substance as boric acid, may effect slight and indirect injury to health, and is capable of seriously interfering with digestion. Dr. H. W. Wiley, of the United States Department of Agriculture, demonstrated in 1905-7, from feeding experiments upon twelve healthy young men, that formic aldehyde, boric acid and salicylic acid are substances which, when added to food, even in small quantities, may exercise a harmful effect on digestion and health. Few of these agents enter normally into the constitution of the human body; and at least they must be regarded as foreign bodies whose ingestion works no possible good, and which, not being foods, do not in any way make amends for the additional work of elimination which their presence demands. Moreover, they enable vendors or manufacturers to deal with stale or badly prepared food, to the prejudice of the more honest tradesmen. If the adulteration is permitted, the vendor should at least be compelled to state the nature and amount of preservative employed.

Opinion is somewhat divided as to the actual harm which results from the use of very small quantities of preservatives in food;[1] but the use of such agents is unnecessary; and it is certain that even so rapidly decomposable a food as milk, when collected and stored with proper regard to cleanliness, and quickly chilled, can be sufficiently preserved, even in the hottest weather, to meet all the requirements of its distribution and use. Food purveyors have not always the knowledge as to the amount of preservative

[1] It is possible that the "epidemic eczema or dermatitis" which has been observed of recent years in various metropolitan poor law infirmaries, and which, attacking principally inmates of advanced age, caused in some outbreaks the deaths of 10 per cent. of those attacked, is due to the consumption of milk containing formalin and possibly other preservatives.

it is necessary to add, and quite unnecessarily large amounts are often detected; moreover, an injurious quantity of preservative may easily be consumed in a meal which includes a number of foods, in each of which there is only a small quantity of preservative. The practice of using preservatives in food also leads to uncleanly treatment, and is often the means employed to render unwholesome food saleable. In several countries preservatives are expressly forbidden by law, and successful results are obtained by pasteurization, sterilization, refrigeration, or chilling. The Departmental Committee appointed to inquire into the use of preservatives and colouring matters in food in the year 1899 recommended the prohibition of the use of formic aldehyde, and that salicylic acid should not be used in greater proportion than 1 grain per pint in liquid food, and 1 grain per pound in solid food. The use of any preservative and colouring agents in milk was condemned. Certain boron compounds might be used in cream and butter when they do not exceed 0·25 per cent. and 0·5 per cent. of boric acid in cream and butter respectively. They found that no preservatives should be used in any invalid or infant food, and that copper salts should not be used for greening preserved fruits and vegetables. Experiments have shown that boric acid in the proportion of 20 grains to the pound prevents objective decomposition, such as is detected by smell, without affecting the growth of coli organisms or Gaertner's bacillus. Its employment may therefore cloak the use of stale meat in sausages without removing or reducing the possibly harmful results of its consumption.

The presence of chemical preservatives in canned or bottled food suggests that by their addition it has been sought to overcome undesirable conditions in the meat itself, prior to canning; but a very small amount of borax may be present in potted material containing ham or bacon from the circumstance that these articles are packed between thin layers of borax before they are sent over to this country, and that while the borax penetrates but little into the fat, it reaches considerable distances into the other tissues.

Preserved vegetables have commonly been found to be coloured (green) by copper sulphate. The coloration is attributed to the formation of a copper salt by an acid derived from phyllocyanin (a derivative of chlorophyll), which body is very inert and insoluble in hydrochloric acid. Any excess of copper combines

with the proteid matter to form copper leguminate, which is practically useless for colouring purposes.

Some authorities have pronounced in favour of the harmlessness of this employment of cupric sulphate when the amount used does not exceed 2 grains (about $\frac{1}{2}$ grain Cu) to the pound of peas, beans, spinach, etc.; but the Departmental Committee appointed in 1899 recommended that the use of copper for colouring food should be prohibited (as in Germany and Austria). In small quantities copper is found naturally in certain foods (notably oysters), and Lehmann assumes that nearly $\frac{1}{3}$ grain may thus be taken in daily.

Sulphate of copper acts as a powerful astringent upon the lining membranes of the stomach and intestines. It also interferes with digestion by reason of its powers of inhibiting the digestive ferments, even when present in very small quantity. In large doses, or in smaller doses frequently repeated, it is an irritant poison, occasioning symptoms closely resembling those due to lead poisoning.

Sweetmeats and *confectionery* are now almost invariably sold free from any injurious colouring matter. The coloration is imparted by careful heating of sugar, by which a variety of shades of yellow and brown may be obtained, or by the use of such harmless organic matters as saffron, turmeric, annatto (yellow), cochineal (red), logwood (violet), and chlorophyll (green). The use of the mineral and metallic salts for colouring purposes—those containing iron, lead, copper, arsenic, chromium, and zinc—is now rarely practised.

An easy and rapid test for the separation of poisonous from harmless colouring matters may be applied as follows: Dissolve some of the sweetmeat in distilled water. If the colouring matter is soluble and is bleached on adding solution of sodium hypochlorite, it is organic and probably harmless. If the colouring matter is insoluble, or is soluble and is not bleached by sodium hypochlorite, it is probably mineral and possibly poisonous.

The aniline dyes are sometimes used for colouring sweetmeats. They are soluble in alcohol and mostly innocuous, if quite free from arsenic, which is usually the case. Picric acid (trinitrophenol), a yellow dye, is injurious; and the same may be said of the yellow colouring matter derived from gamboge, and a few aniline dyes, such as: naphthol green, aniline yellow, Martius' yellow, methylene blue, and gentian violet.

SHORT TABLE OF THE MORE COMMON ADULTERATIONS OF FOODS AND BEVERAGES.

I. Articles in Respect to which Legal Standards have been Imposed.

Articles of Food.	Nature of Adulteration.	Legal and other Standards.
Milk	Addition of water and skimmed milk. Abstraction of fat.	3 per cent. butter-fat; 8·5 per cent. solids non-fat (Board of Agriculture). The Public Health (Milk and Cream) Regulations, 1912, prohibit the addition of all preservatives to milk intended for sale for human consumption.
Skimmed milk	Occasionally enriched with an emulsion of some foreign fat or by condensed milk.	8·7 per cent. of milk solids other than fat (Board of Agriculture).
Cream	Artificial thickening agents: Sucrate of lime, gelatine, starch-paste, condensed milk, etc.	The Public Health (Milk and Cream) Regulations, 1912, prohibit the addition of any preservative to cream containing less than 35 per cent. by weight of milk-fat; to cream containing more than 35 per cent. by weight of milk-fat, boric acid or borax, or a mixture of these, or hydrogen peroxide, may be added, but the vessel containing the cream must be labelled. By the Amending Order of 1916, the boric acid added must not exceed 0·4 per cent. by weight, and receptacles containing such preserved cream must be labelled "Preserved cream containing boric acid not exceeding per cent. Not suitable for infants and invalids." No thickening substance may be added.

Butter	The partial or complete substitution of butter-fat by other animal and vegetable fats (beef-stearin, cocoa-nut, cotton-seed oil, etc.).	
	Incorporation of excessive amounts of water or salt.	Not more than 16 per cent. water (Butter and Margarine Act, 1907). 24 per cent. permitted in " milk-blended " butters.
	Chemical preservatives (boric acid and borax) and colouring agents (annatto, aniline dye).	
Margarine	Excessive water. Chemical preservatives and colouring agents as in butter.	Not more than 16 per cent. of water (Butter and Margarine Act, 1907). Not more than 10 per cent. of butter-fat (Sale of Food and Drugs Act, 1899).
Spirits	Insufficient alcohol from dilution with water.	Brandy, whisky, gin, and rum may not be sold below 35° under-proof (Licensing Act, 1921).
Vinegar	Sulphuric acid, wood acid, excess of water, calcium bisulphite, salicylic acid. Insufficient strength.	Local Government Board is of opinion that the strength should not be less than 4 grammes of acetic acid in 100 c.c.
Lime and lemon juice	Tartaric acid, sulphuric acid, water.	In lemon juice the specific gravity should not be less than 1030, and there should be at least 30 grains per ounce of citric acid (British Pharmacopœia and Board of Trade).

THE MORE COMMON ADULTERATIONS OF FOODS AND BEVERAGES—*Continued.*

2. ARTICLES IN RESPECT TO WHICH NO LEGAL STANDARDS HAVE BEEN IMPOSED.

Article of Food.	Nature of Adulteration.
Cheese and Margarine Cheese	Of same nature as those of butter. Metallic antiseptic solutions have been brushed over the surfaces.
Lard	As in butter.
Tea	Previously used leaves. Foreign leaves (elder, willow, sloe, etc.).
Coffee	Roasted chicory, certain roots and starch flours, artificial coffee-beans, caramel.
Cocoa	Starch, sugar.
Wine	Sugar, various ethers, tannin, logwood, sulphate of lime and alum, boric and salicylic acids, sulphites, inferior brandy to fortify.
Beer	Glucose often substituted for malt; other bitters as substitutes for hops; calcium and sodium salts (sulphites), sodium bicarbonate, sulphuric acid, boric and salicylic acids, common salt.
Fruit juices	Salicylic acid and sulphites.
Wheat flour	Rarely by addition of other flours and meals (rice, maize, etc.). Phosphates, etc., as "improvers."
Oatmeal	Barley-meal, etc.
Arrowroot	Potato starch, etc.
Mustard	Turmeric and aniline yellow, starch.
Pepper	Rice, etc.; starch; ground olive-stones, etc.
Sugar	Beet-sugar dyed to resemble cane-sugar.
Honey	Artificial comb from paraffin-wax, etc.; syrups.
Canned foods	Chemical antiseptics, colouring agents.
Jams, jellies, etc. ..	Apple-pulp, artificial pips, benzoic acid and salicylic acid, and occasionally boric acid, as preservatives.
Sausages, bacon, hams, etc.	Boric acid and borax, sulphites, as preservatives.

N.B.—The practice of any of the above forms of adulteration renders the vendor liable to a prosecution under the Sale of Food and Drugs Acts, for the offence either of selling an article of food or drink which is not of the nature, substance, or quality demanded, or of selling any article of food or drink which has been rendered injurious to health.

CHAPTER IX

INFECTION—COMMUNICABLE DISEASES AND THEIR PREVENTION—HOSPITALS

Infection.

Certain diseases of men and animals have long been known to be communicable from one individual to another, and recent investigations have shown that some of these diseases are not only communicable from one individual of the same species to another, but are interchangeable between animals and men, and between men and animals. Various doctrines have been held at different times as to the nature of the contagia in these diseases, but the theory of their constitution which is embraced in what is known as the "germ theory of disease" need only be discussed here.

The germ theory of infection assumes that the infective agents are minute living particles, organized in structure and for the most part capable of independent life both within and without the animal body. These organic particles are believed to form part of that large class the *schizomycetes*, which embraces the lowest and least developed forms of vegetable life, and constitutes a link, as it were, between the two great divisions of the animal and vegetable world. To this class belong the bacilli, micrococci, spirilla, vibriones, etc., which exist in such enormous numbers in every region and climate.

In infectious disease, there is a period of incubation which may be supposed to arise from the delay necessary to allow of the contagious particles overcoming the influences exerted against them by the antagonistic cells and fluids of the body, thus enabling the growth and multiplication of the contagious particles to take place; during the course of the fever specific bactericidal substances are produced in the blood, which either are directly poisonous to the specific microbes, or else enable the

leucocytes to ingest and destroy them; and specific antitoxins are also generated, which counteract the bacterial toxins. As a result of these defensive actions on the part of the organism invaded by the disease, the fever runs its course, recovery ensues, and the body is rendered unassailable by a similar infection for months or years, or in some cases until the end of life.

It is evident that the infective element, once introduced into the animal body, generally grows and multiplies enormously; but the organisms of diphtheria and tetanus multiply locally only to a limited extent, producing the symptoms by the soluble toxins which they elaborate. The least atom of infectious material serves to inoculate small-pox in a susceptible person, but the infectious matter produced in the course of the disease would be sufficient to inoculate many thousands. In each special disease the contagion multiplies chiefly in those tissues—the mucous and epithelial—which are more especially affected by it, and the infection is cast off from the body in large part with the secretions of these tissues. Freed from the body, the infection may be conveyed directly from the diseased to the healthy, or it may lie dormant in the clothes or furniture of the sick-room for a certain period, and still retain its contagious properties.

This property, possessed by some infections, of retaining unimpaired their powers of infection for long periods after leaving the body, is further evidence in favour of their bacterial nature. It is known that many bacteria are propagated by sporulation, and that the spores can resist extremes of temperature and drying which are destructive to the fully developed organism. That liquids, gases, or any non-living material could retain infective properties for long periods after expulsion from the body, when subjected to the physical and chemical forces opposed to their stability, is highly improbable.

In some diseases, the infection does not appear to be capable of maintaining an independent existence outside the animal body, except possibly for short periods. In these cases the infection is conveyed by direct contact or inoculation.

The microbic origin of many communicable diseases may be considered to be established beyond doubt, and this fact is strong presumptive evidence in favour of the remainder—in which no such connection has as yet been positively traced—being causally dependent upon specific micro-organisms. Koch has laid down certain conditions, upon the proof of which alone can it be

definitely stated that a particular micro-organism is the cause of a certain disease. They are as follows:—

1. The micro-organism must be found in the blood, lymph, or diseased tissues of man or animal, suffering from or dead of the disease.

2. This micro-organism must be isolated from the blood, lymph, or tissues, and cultivated in suitable media outside the animal body. These pure cultivations must be carried on through successive generations of the organism.

3. A pure cultivation thus obtained must, when introduced into the body of a healthy susceptible animal, produce the disease in question.

4. In the inoculated animal the same micro-organism must again be found.

It is evident that, postulate No. 3 being rarely applicable to human beings, the complete sequence of proof cannot be arrived at in the case of exclusively human diseases. But in the case of the diseases affecting both men and the lower animals, inasmuch as the animals can be submitted to processes of inoculation, the entire chain of proof can be substantiated.

It is not desirable to retain the term "contagious," as distinct from "infectious," in regard to the communicable diseases, unless the term "contagious" is limited to those diseases which are only transferable by direct inoculation, such as syphilis. The term "zymotic" is usually applied to those communicable or infectious diseases which occur in epidemics; but nowadays it is customary to restrict the term "zymolysis" to the action of the chemical or unorganized ferments known as enzymes. Therefore, zymotic, as a term, does not necessarily imply that the disease is dependent upon a living organized body or germ.

A distinction may be made between "infection" and "intoxication"; by the former is implied an invasion of the body by a living germ, and by the latter the poisoning of the body by chemical agents, usually the products of the activity of a living germ. Anthrax affords a typical example of infection, in which the bacillus invades the whole body; and tetanus affords an example of "intoxication," for in this disease the bacillus is localized to the seat of injury, and the toxic products are absorbed from this spot into the general system.

The use of the word "specific" as applied to these diseases presupposes a specific origin for each—an origin, that is to say,

from a pre-existing case of the disease by means of a specific virus or organized living germ. The specific origin of most of the communicable diseases can hardly be doubted. The eruptive fevers are specific and they breed true; *i.e.*, a case of measles, for instance, cannot give rise to mumps or whooping-cough, but only to measles, and the infection cannot arise *de novo*, but must be sought for in a pre-existing case. But the true specificity of some zymotic diseases is not yet thoroughly established, such as hospital fevers, summer diarrhœa or zymotic enteritis, and catarrhs of the air passages.

Hospital fevers, however, are certainly due to micro-organisms either in the air of the wards, or on the patient's skin or wound. Catarrhs, too, are probably always due to organisms such as *Micrococcus catarrhalis*, *Pneumococcus*, or *B. septus*, which are present at one time or another in the nose or throat.

Diarrhœa may be induced by chills; but in all probability a chill only lowers the resisting power of the lymphoid tissue in the intestinal walls, thus enabling the micro-organisms present to multiply abnormally.

The eruptive fevers are remarkable, chiefly for occurring in epidemics, often at regularly recurring periods. The infection being very commonly disseminated for short distances through the air, it is easy to understand how these diseases, once introduced into a community, spread with considerable rapidity, until the diminution of susceptible persons or some other undetermined factor causes the epidemic to languish and finally die out.

There are other diseases which at times take on epidemic extension, but are mostly endemic; that is to say, they are always present in certain localities where conditions of excremental pollution of water, air, food, or soil favour the passage of the specific virus from one individual to another; and this constant occurrence of isolated or sporadic cases gives rise to the sudden and widespread dissemination termed an epidemic at certain seasons, when external conditions are favourable. The introduction of public water supplies into towns has, no doubt, tended to cause certain epidemics of enteric fever and cholera to reach further and spread wider than formerly; for if a public water supply is specifically polluted at its source, the contagion is carried to a far larger number of households than could possibly be the case where each house has its own well or spring.

When an epidemic assumes very extensive (geographical) proportions, it is termed a pandemic. For instance, cholera has often been widely distributed in both Asia and Europe at one and the same time, and influenza and plague exhibit the same pandemic tendencies.

Various theories have been advanced to explain the causation and course of epidemics of disease. Of such explanations the most feasible one is that the organism responsible for an epidemic suddenly assumes great reproductive or infective power, a storing-up of energy having gone on till the point of liberation is reached, and then the powers of infectivity or reproduction continuously decrease, the process being a rhythmic one of increase and decrease in the disease organisms. Another view that has been advanced is that epidemics are controlled by the exhaustion of the susceptible persons in the community; and, again, it has been maintained that epidemics depend upon a diminished resistance of the population to disease, and so far as certain infections are concerned there is evidence to support this view.

The subject of bodily susceptibility to the action of the various infections requires a passing notice. It is evident that in early childhood the bodily susceptibility to various infections is very great, and this susceptibility diminishes with advancing age. The protective influence in the case of some diseases of a previous attack, the state of health of the individual, and hereditary predisposition, are well known to determine the degree of bodily susceptibility; and there are other causes at work, which are less well known. The virulence of the organism at the time it enters the body, and the quantity of the organisms (dosage) which gain admission, are circumstances which may determine or otherwise an attack of the disease.

Among the diseases of animals common to man, in which a specific bacterium has been isolated, are anthrax (malignant pustule in man), tubercle, glanders, actino-mycosis, erysipelas, tetanus, plague, foot-and-mouth disease, diphtheria, and malignant œdema.

Anthrax, Malignant Pustule, or Wool-sorter's Disease.—The bacilli are found in enormous numbers in the blood of animals dead of anthrax. When exposed to the air they form spores, which are much more resistant to extremes of heat and cold, to drying, and to chemical reagents than the fully developed bacilli.

Tubercle.—The *Bacillus tuberculosis* is found in all tubercular deposits, and is seen with a high power of the microscope to consist of small, usually straight rods; but they may frequently be slightly curved. The bacilli are found in the sputa of phthisical patients; and in man the disease is set in action by the bacilli introduced, by the usual method, through the mucous membrane of the air passage or intestinal canal, through the tonsils or genital tract, or occasionally by direct inoculation into a wound or abrasion of the skin.

In the lower animals (monkeys, cattle, fowls, guinea-pigs, rabbits, etc.) artificial tuberculosis can be readily produced by inhalation of a spray containing tubercle bacilli, by feeding experiments with tuberculized food, and by direct inoculation, the channels of infection being the same as those of man.

The question of susceptibility, hereditary or acquired, to the tubercular virus is of the greatest interest, and is deserving of most careful investigation. It is evident that tubercle bacilli must be very widely scattered in the air of houses and towns, and yet the number of persons who contract tubercle, and show definite symptoms of tubercular infection, is very small compared with the numbers that must from time to time be exposed to the contagion. The very large proportion of adults, who have died of some non-tubercular disease, upon whom autopsies have been made, and whose internal organs present evidence of some old tubercular lesion, either caseated, cicatrized, or otherwise cured and inactive, is evidence of the widespread diffusion amongst civilized communities of the tubercular infecting agent, and of the general resisting powers of the individuals attacked to the more fatal forms of tuberculosis. Unlike the eruptive fevers, tubercular diseases run no definite course; and although it is now certain that recovery from tubercular lesions of the lungs and of other organs is by no means infrequent, yet there is no apparent immunity conferred from subsequent attack.

Glanders.—The bacillus of glanders (*Bacillus mallei*) consists of a rod about the size of tubercle bacilli. The inoculation of pure cultivations, or of infectious material (*e.g.*, pus), from an infected horse into another produces the characteristic disease, the bacilli being found after death in the affected organs and diseased tissues.

In *erysipelas*, a streptococcus has been found occupying the lymphatics of the skin at the circumference of the erysipelatous blush. A pure cultivation of the streptococci produces erysipe-

latous inflammation when inoculated into animals and into men (as has been done for the relief of lupoid and cancerous affections); but sometimes suppuration is the result of the injection, and it is now believed that the streptococcus of erysipelas and the *Streptococcus pyogenes* are identical, the different effects produced being dependent upon:—

1. Mode of entry and site.
2. Resisting power of the tissues at the time.
3. The variable virulence of the streptococcus.

The specific organism in *tetanus* is a bacillus which probably exists widely distributed in dust, dirt, and in soil. During the Boer War, which was fought for the most part on wild veldt or uncultivated land, there was a very remarkable absence of tetanus-infected wounds. During the Great War (1914-1918) the fighting in France and Flanders was waged on land long occupied, highly farmed, and much manured, with the result that tetanus infection of wounds was comparatively common, and an ever-present danger, involving the routine administration of anti-tetanic serum to the wounded at the earliest possible opportunity. The bacillus gains an entrance into the body through scratches and wounds inflicted by substances contaminated with dirt containing the organism or its spores. Cases of so-called idiopathic tetanus are probably due to similar inoculations through scratches or wounds that have passed unnoticed, such as the bite of an insect, especially in the tropics.

Klebs, Loeffler, Roux, and Yersin have isolated a bacillus from the surface of the mucous membrane in cases of *diphtheria*. From cultivations of this bacillus a soluble poison has been obtained, which causes the symptoms of diphtheria in varying degrees of intensity according to the dose.

The bacillus of *typhoid* fever (known as the Eberth-Gaffky bacillus) is constantly present in the alimentary canal, in the mesenteric glands, and in the spleen of fatal cases of this disease.

In Asiatic *cholera*, Koch discovered a comma-shaped bacillus in the intestinal walls and evacuations. In *relapsing fever*, a motile spirillum (*Spirillum Obermeieri*) has been found in large numbers in the blood during the relapses, which organism is absent in the non-febrile periods, and which, when inoculated into monkeys, induces a disease analogous to human relapsing fever. It is probable that this is not a bacterium, but a spiro-

chæte protozoon, which has two hosts—namely, man and body lice, and is conveyed to the former by the bite of the latter. Various micro-organisms have been described as associated with other diseases.

There are some diseases whose microbic origin is not yet definitely established, but in which there is a very strong probability of such a mode of occurrence. Chief among these are scarlet fever, typhus fever, mumps, leprosy.

From vaccine pustules in a calf and from human vaccine lymph Klein isolated a minute bacillus, which is probably the specific organism of *vaccinia ;* and Copeman has found similar bacilli in stained sections of vaccine pustules. Rüffer and others have described a protozoon in the epithelial cells around small-pox and vaccine pustules. From acute abscesses, boils, carbuncles, the abscesses of pyæmia, acute osteomyelitis, and *puerperal fever*, the *Staphylococcus pyogenes aureus* and *albus* and *Streptococcus pyogenes* have been obtained, which are pathogenic to certain animals. An organism (pneumococcus, Fraenkel and Weichselbaum) has been found in the exudations of croupous *pneumonia*, which is pathogenic to mice, inducing a very acute septicæmia. This pneumococcus or diplococcus is also said to be present in the saliva of healthy people and of those who have suffered from pneumonia. Its presence may explain the liability to recurrence of this disease, in association with chill or other exciting cause. In *ulcerative* (*infective*) *endocarditis* a micrococcus has been observed in the endocardial ulcerations; and the *Meningococcus intracellularis* is the cause of *epidemic cerebrospinal meningitis*.

Thus there is still wanting, in the case of some communicable diseases, the complete chain of experimental proof necessary to establish the causal relationship of the organisms which have been described as associated with them. The experimental inoculation of the lower animals with the supposed vira of human diseases, to which they are not known to be naturally liable, affords little assistance to the completion of the proof, even if symptoms are produced in the animal of an analogous nature to those characteristic of the disease in man. The constant association of a certain organism with a certain disease, in all climates and races of men, is, no doubt, practically a strong point in favour of the specific nature of the microbe, but logically it does not prove that the microbe is an indispensable antecedent

(cause), or even an antecedent (one of several causes in conjunction), of the disease, or, indeed, that it is anything more than a consequence.

Recent research points to the symptoms of infectious disease being caused not directly by the action of the microbes themselves upon the tissues, but by the production of soluble poisons termed "toxins." Observations have already been made in the cases of anthrax, tetanus, diphtheria, puerperal fever and rabies, that these diseases are—or may be—caused by the specific microbes producing, as the result of their activity, these soluble poisonous toxins, which exert a direct action upon the tissues of the body; and if such is the case in these diseases, the symptoms of many others of an allied nature may also be due to the chemical products of the microbes.

Immunity and Protection.—Immunity is either *natural* or *acquired*. By *natural immunity* is meant that certain species of animals or certain races of mankind are unaffected by certain diseases, even although exposed to infection. It seems probable that this condition of natural immunity, which is also to be seen in certain individuals of species or races which themselves are not naturally immune, is due not to the fact that the specific micro-organisms of the disease are inert, subsequent to invasion of the body, but that there is a very high degree of resistance on the part of the invaded organism, so that infection is not followed by any effects of an observable nature.

Immunity is *acquired* by the individual passing through an actual attack of the disease, or is produced artificially by protective inoculations. This artificially acquired immunity is of two kinds: (1) *active*, (2) *passive*.

Active immunity against a disease may be conferred by the injection into the blood or tissues of the living specific microbes of that disease in (*a*) non-fatal doses, (*b*) in an attenuated condition, (*c*) or as dead bacteria. This weakened or attenuated condition of the specific microbe may be brought about (1) by growing the cultures in a current of air, as used by Haffkine for preparing anti-cholera vaccine; (2) by growing the cultures at abnormal temperatures, as used for attenuation of anthrax by growth at 42° to 43° C.; (3) by growing the cultures in media to which some weak antiseptic (such as phenol 1 in 600) has been added, or by injecting such antiseptic along with the organisms, when inoculating—as, for example, Gram's iodine solution or

iodine trichloride is added to cultures of tetanus before inoculating a horse, for without such attenuation a fatal result might ensue; (4) by drying the virus in air, as in the Pasteur system of inoculation against rabies; and, lastly, (5) by passing the specific organism through the tissues of another animal, as seen in the calf-lymph vaccination for small-pox.

Active immunity may also be conferred by the injection of dead cultures of the specific microbe (enteric fever and plague). The immunizing agent in such dead cultures is either the intracellular toxins—the toxins formed within the cell membrane of the bacteria—or the extracellular toxins produced by the growth of the bacteria in the culture media which surround them. The former are obtained by collecting the growth from the surface of a solid medium, and then sterilizing by heat, the latter by employing the filtrate from a broth culture which has been made to traverse a germ-proof filter.

Passive Immunity.—Passive immunity is conferred by the injection of the blood serum of an animal which has been actively immunized by any one of the above-mentioned processes. It is termed "passive" because the individual takes no part in the production of the immunizing agent. Such serum may be *antitoxic*—*i.e.*, it protects the animal into which it is injected from the toxins of the specific microbe, having, however, no preventive action on the living micro-organism—or it may be *antibacterial*, preventing the multiplication of the living microbes, but having no antitoxic effects. Some sera are both antitoxic and antibacterial. Passive immunity is not lasting, whereas active immunity may be of considerable duration.

Phagocytosis.—The rôle of the body cells in the production of immunity was discovered by Metchnikoff, and was termed by him "phagocytosis," meaning the capacity displayed by certain amœboid cells for the engulfing and subsequent destruction of micro-organisms, red blood corpuscles, cells, and cell débris. Metchnikoff classified the phagocytes in two groups: (1) *Macrophages*, (2) *Microphages*, the former consisting of the "fixed" cells of the spleen, of the lymphatic glands, and of the endothelium, their activities being chiefly directed against cells and cell débris; whilst the latter consist of the "free" or "wandering" polymorphonuclear leucocytes of the blood, whose function is the destruction of micro-organisms.

The mere presence of phagocytes and their increased numbers

is not, however, enough by itself to produce phagocytosis and the conferring of immunity by the destruction of the invading bacteria. Certain other bodies must have made their appearance in the blood serum before the phagocytes are adequately endowed with their powers of engulfing and destroying bacteria. The principal of these antibacterial substances produced in the blood serum as the result of the invasion of the tissues by bacteria are:—

Opsonins.—These were discovered by Wright and Douglas in 1903, their function being to prepare the bacteria for ingestion by the phagocytes (*opsono* = I cater for). Opsonin is a body of unknown constitution; but its chief properties are, in addition to rendering the bacteria capable of absorption by phagocytes, (1) its instability, as it disappears from serum on standing after a few days; (2) its capacity for being injured by temperatures over 50° C., and its destruction by heating to 60° C. for ten minutes. It is, then, what is known as *thermolabile*. The opsonin, which is produced in a serum as the result of an invasion by a specific bacterium, is effective only for that bacterium, and for no other bacteria.

Opsonins are normally present in the blood serum, there probably being a distinct opsonin for each possible bacterial invader of the body. But it is found that the amount of any specific opsonin may be increased by injection into the body of dead cultures of the specific microbe, and it is to this increase that may be ascribed the immunizing effect of such injections. For a short period after the injection there is a "negative phase," but this is rapidly succeeded by a "positive phase," when the "opsonic index" is found to be heightened. The "opsonic index" is the ratio of the average number of specific microbes engulfed in a phagocyte from the blood of any individual to the number so engulfed in a phagocyte from the blood of a normal healthy individual. To obtain this index, small and equal quantities of (1) the blood serum, (2) an emulsion of the organism in question, and (3) leucocytes washed free from plasma, are mixed and sealed in a capillary tube, and then incubated at 37° C. for fifteen minutes. Films are then prepared, appropriately stained, and examined under the microscope. The opsonic index has been used for diagnostic purposes in tuberculosis, in which disease the index is often low or very irregular. In healthy persons the index is more regular, varying in individuals from 0·8 to 1·2.

Phagocytosis and the opsonic powers of blood serum have been studied chiefly in connection with invasions of the body by the following organisms: *Staphylococcus, Bacillus tuberculosis, B. pestis, B. melitensis, B. dysentericus* (Shiga), *B. coli, Pneumococcus, Streptococcus, B. anthracis, B. typhosus*, and *Vibrio choleræ*. *B. diphtheriæ* appears not to be affected by opsonins; and in regard to all the above infections it must be borne in mind that the question of phagocytability is dependent upon virulence very largely, a freshly isolated virulent bacterium being frequently quite resistant to phagocytosis, whilst the same bacterium, which has been sub-cultured in nutrient media, may be phagocyted with facility. Some of the infective agents of disease appear also to be capable of defending themselves against the immunity-producing forces of the body, and of eventually producing *resistant strains*, which can perpetuate the race, uncontrolled by the defensive powers of the host.

Agglutinins.—These are substances produced in the blood serum as the result of the invasion of infective bacteria, which cause the particular bacteria, in response to which they appear, to agglutinate, *i.e.*, to lose their motility, if they are motile, and to collect into clumps, which, outside the body (*in vitro*), separate out from the fluid and deposit at its lowest part. The bacteria are not killed by agglutination. Although these agglutinins are specific for specific bacteria, they also appear to be able to exert a partial agglutinizing effect upon bacteria of allied species. Thus a typhoid immune serum possesses, besides its greatly increased agglutinating power for *B. typhosus*, an agglutinating power in less degree for *B. paratyphosus*, which is notably above the agglutinating power of normal serum for the latter microbe.

The rôle played by the agglutinins in the production of immunity appears to be slight, as neither the capacity for growth, nor the virulence of the agglutinated bacteria, is appreciably altered thereby. The agglutinating power of the serum of an animal gives no indication of the degree of the animal's immunity against the particular micro-organism. Nevertheless, the presence of agglutinins in a serum affords valuable indications, (1) in the diagnosis of various bacterial diseases, (2) in the differentiation of bacteria found in various lesions. Agglutinins exert their effects upon dead as well as upon living bacteria.

Precipitins.—These, like the agglutinins, are specific substances found in the serum of animals which have received injections of a

particular micro-organism, or of solutions of animal or vegetable albumins. These precipitins, when introduced into a clean culture filtrate of the specific (homologous) micro-organism, or into a clear solution of the particular albumin which gave rise to them, produce a precipitate. Like the agglutinins, the precipitins probably play but a very small part in the production of immunity. They have, however, much interest for medico-legal purposes, and especially for determining the origin of blood stains. Thus, by injecting rabbits with the blood of man or other animals, sera can be obtained which give a precipitate in the serum of the blood used for the injection, but not in the serum of other kinds of blood. The precipitin reaction is also found to be common for the sera of animals of closely related species; thus, the sera of anthropoid apes give the reaction when the rabbit has been injected with human blood; and a similar relationship has been observed between the sera of the horse and the ass, the sheep and the cow, the hare and the rabbit, and the hen and the pigeon.

Bacteriolysins.—These are specific substances found in the blood of animals which have been immunized against a specific bacterium. They cause the specific bacteria to shrivel up and eventually to become converted into granules, at the same time rendering motile bacteria immotile, and depriving them of their staining properties. The effective agent of these bacteriolysins is a substance which was called by Ehrlich "*amboceptor*," because, on the one hand, it attaches itself to the bacterium, and on the other, to the substance called "*complement*," which must be present in the serum, and capable of attachment through the amboceptor to the bacterium, if bacteriolysis is to take place. The amboceptor is *thermostable*, *i.e.*, resists heating at 55° C. for one hour, and is *specific* for the particular kind of bacterium in response to which it has been produced; whilst complement is *thermolabile* (destroyed by heating for half an hour at 55° C.) and is *non-specific*, being present in the blood of non-immunized animals, and not being increased during the process of immunization. Complement will, therefore, unite with any specific amboceptor and its corresponding bacterium; but it disappears spontaneously within a few days from serum withdrawn from the body. A serum is said to be "*inactivated*" when its complement has been destroyed by heating to 55° C. Not all bacteria are subject to bacteriolysis. It is limited chiefly to the typhoid and

paratyphoid groups and the cholera organism. The part played by bacteriolysins in the production of immunity is not yet fully understood.

Hæmagglutinins.—These are substances, similar to bacterial agglutinins, which are produced in the serum of an animal which has been inoculated with the red blood corpuscles of another species. Such serum mixed with a suspension of the corresponding red blood corpuscles causes these to clump and sink to the bottom.

Hæmolysins.—These are substances similar to the bacteriolysins, which are produced in the serum of an animal which has been inoculated with the red blood corpuscles of another species. Such serum mixed with a suspension of the corresponding red blood corpuscles causes the latter to *lake*—their envelopes are ruptured, and the hæmoglobin escapes into the fluid, which becomes uniformly tinged red, the altered corpuscles sinking to the bottom of the fluid.

Like the bacteriolysins, the hæmolysins are amboceptors. They are unaffected by a temperature of 55° C.; and they are inert unless complement is present, and free to unite with them. They are also specific for the particular red blood corpuscles in response to which they have been produced.

Hæmolysins are of special interest in connection with the *Wassermann reaction for the diagnosis of syphilis*. For carrying out this test the following substances are required, viz.: (1) *The antigen*; (2) *the patient's serum*; (3) *complement*; (4) *red blood corpuscles*; (5) *hæmolytic amboceptor*.

Antigen is the name given to a substance which gives rise to the formation of an antibody. Antigen may be a toxin, a bacterial emulsion, a bacterial extract, an emulsion of blood corpuscles, a solution of albumin, etc. The antigen originally used for the test was a watery extract of the liver of a syphilitic fœtus; but it has now been found that alcoholic extracts of normal organs yield an antigen which is as effective as the syphilitic fœtal liver. Complement is obtained from fresh guinea-pig serum. The blood corpuscles are obtained from defibrinated sheep's blood, and are centrifugalized and washed in normal saline solution, so as to free them from serum. Hæmolytic amboceptor is obtained from the serum of a rabbit which has been injected with the washed red blood corpuscles of a sheep.

The patient's serum, the complement, and the antigen are mixed in a tube in suitable dilutions, and placed in an incubator at 37° C. for one hour. The hæmolytic amboceptor and the suspension of sheep's corpuscles in suitable dilutions are then added, and the mixture incubated for two hours at 37° C. After twelve hours of standing in the cool, the result may be observed. If the serum is from a syphilitic patient, the complement has fixed itself to the syphilitic antibody or amboceptor present in his serum, which is itself attached to the antigen, and no hæmolysis results, all the blood corpuscles being found at the bottom of the tube, leaving the fluid above clear and colourless. If the patient is not syphilitic, hæmolysis takes place, as the complement is free to unite with the hæmolytic amboceptor, there being no specific amboceptor present; and, as a result, no corpuscles are found at the bottom of the tube, and the fluid becomes deeply "laked" or stained with hæmoglobin. Between the two results of complete positive reaction and complete negative reaction various grades may be found, dependent upon the stage of the disease reached, and the corresponding presence of syphilitic antibodies in the patient's serum.

Antitoxins.—These are antibodies produced in the blood of an animal in response to the injection of bacterial toxins, or as the result of the natural invasion of the body by a toxin-producing bacterium. Each antitoxin is specific, and is effective only against the toxin produced by the particular bacterium in response to which it appears. Toxins are of two kinds—exotoxins, produced in the medium in which the bacterium thrives; and endotoxins, those existing in the cell of the bacterial element itself, and set free only by the disintegration of the cell element. Microbic diseases fall into two groups, according as the poisons leading to the symptoms of the disease are chiefly exotoxins or are chiefly endotoxins. Of the first kind are tetanus and diphtheria; of the second, cholera, typhoid, and diseases due to the pyogenetic cocci (streptococcus, pneumococcus, etc.).

Antitoxin neutralizes or renders inert its own toxin; and this effect is produced both in the body itself, as in the well-known result following the injection of diphtheria antitoxin into persons suffering from this disease, and also *in vitro*, or outside the animal body, as can be seen by mixing antitoxin serum with a lethal dose of diphtheria toxin, and then injecting into a guinea-pig. The exact method by which antitoxin neutralizes toxin, so that the

latter loses its effects on the tissues, is unknown. The combination of toxin with antitoxin may partake of the nature of a chemical reaction, or it may be that a physical effect is produced, on the supposition that toxin and antitoxin are bodies in a colloid state, which may combine so as to neutralize each other without any chemical union.

In diseases such as diphtheria, tetanus, and bacillary dysentery, where toxins are largely produced at the site of local lesions, and thence absorbed into the circulation, the production of immunity is intimately connected with the formation of antitoxins in the blood in response to the stimulus of the toxins locally secreted. In most other diseases of an infective character, phagocytosis and the production of antibodies in the serum, which assist or render phagocytosis effective, would appear to be more intimately concerned with the production of immunity than antitoxin formation. It seems probable, however, that in all diseases of this class which confer some degree of immunity to subsequent attack, the defensive powers of the body may be concerned both in phagocytosis and in antitoxin formation, the relative activities of each varying with the nature of the disease, the stage of the disease, and the dosage and virulence of the infecting organism.

Infections of the human body may be broadly conceived as being of two classes: (1) generalized, and (2) localized. There is no true dividing line between the two, as generalized infections may become localized, or *vice versa;* but in the former the blood is invaded by the organism, and a general systemic infection results, whilst in the latter the organism is more or less restricted to a certain localized area; and although organisms may at times travel beyond the infected area, and enter the blood stream, the symptoms of illness are more attributable to the absorption of toxins from such area than to bacillary invasion of the systemic circulation. The localization of the invading microbes is for the most part effected by inflammatory processes in and around the site of invasion, which tend to circumscribe the mischief by preventing any large access of the invaders to the blood and circulation. The well-known dangers of infections of the general septicæmic type are probably due to rapid multiplication of the invaders in the blood and tissues, and the production of toxins in dangerous quantities before the resisting powers of the body and the protective actions of opsonins and phagocytes can be brought into play. In such cases curative

inoculations with dead or living cultures of the specific bacteria would probably have a deleterious effect, as the ensuing "negative phase" would only heighten the dangers of toxin poisoning already in progress; but injections with sera, having antibacterial properties, might here serve a useful purpose.

In the more chronic localized infections, such as acne, boils, carbuncles (Wright), where there is failure to overcome the invading microbe, owing to the very success which has attended the inflammatory processes in their endeavours to isolate the virus at the site of entry, curative inoculations with suspensions of the dead bacilli have been found highly beneficial, as they appear to enable the phagocytes to penetrate into the inflamed area, and there attack the invaders in their entrenched position.

The best curative results are, however, seen in the case of the diseases, such as diphtheria and tetanus, in which the symptoms are due to toxins absorbed from the specific microbes which are themselves localized—in the fauces (diphtheria) or at the site of entry of the virus in a wound (tetanus). If injected sufficiently early in the disease before toxin formation has been carried to a dangerous length, the early arrest of the disease may be relied upon. Injections of diphtheria antitoxin are also employed for immunizing purposes in the case of diphtheria "contacts" and "carriers." The immunization so produced is dependent upon the extent to which the serum is anti-microbic as well as antitoxic, and is no doubt of an evanescent character; but it may be sufficient to confer immunity for a period, when there is a considerable risk of infection; and in the case of "carriers" it may prevent the Klebs-Loeffler bacillus present in the faucial or nasal mucous membranes from effecting such a lodgment or assuming such virulence as to eventuate in a diphtheritic attack.

Anaphylaxis.—If an animal is injected with an albuminous substance, such as the serum of an animal of a different species, organic extracts, bacterial extracts, etc., a second injection of similar material will produce, after a definite period, what are known as symptoms of anaphylaxis. A state of hypersensitiveness is induced to which the body reacts on the second injection. The incubation period—*i.e.*, the interval elapsing between the first or "sensitizing" injection and the date at which anaphylactic phenomena may occur—appears to vary with the original dose. If this has been small, the incubation period may be short—eight to twelve days; if the dose has been a large one, the period

may be one of weeks or months. Should a second fairly large dose be given before the end of the incubation period, the animal is de-sensitized, or rendered immune to anaphylaxis. In man the chief symptoms of anaphylaxis are œdema at the point of injection, nausea, vomiting, dyspnœa, fever, muscular and articular pains, and depression, followed later by urticarial eruptions accompanied by much itching, glandular swellings, and inflammations of mucous membranes. These symptoms may come on within four to six hours from the second injection, or be delayed for several days (five to fifteen). These anaphylactic symptoms are probably due to antibodies formed in the blood as the result of the first injection, which, on the second injection, unite with the albuminous substance (antigen) introduced into the system; and this union of antibodies with antigen is thought to be capable of developing marked toxic capacity. The incubation period is necessary for the formation of antibodies in sufficient quantity to unite with the antigen of the second injection.

"This theory supplies a simple explanation of all the known phenomena in question, and shows their relation to the previously discovered processes of immunity—*i.e.*, accounts for it as a true antigen-antibody reaction. Thus in a normal animal, antibody, if it exists at all, is present only in very small amount. A single dose of antigen, producing first a negative phase, subsequently calls forth a larger amount of antibody than in the untreated animal. These two processes explain the latent or incubation period, during which no sensitization is found. At the end of that period antibody is present in such amount that a second injection of antigen is almost at once subjected to lysis with the production of anaphylatoxin as *in vitro*; but in cases where by repeated injections immunity has been conferred the lysis proceeds even more rapidly than above, with the result that the toxic stage of proteolysis is so rapidly passed and the non-toxic stage reached that there is never sufficient toxin in the blood at any one time to cause symptoms" (Wyard).

Anaphylaxis in the human subject is of interest in connection with serum therapy, and especially with diphtheria antitoxin, the vehicle for which is horse serum. Fresh serum is more toxic in this respect than serum which has been kept; so it is a good rule not to use any serum for therapeutic purposes which is less than two months old. The toxicity may also be diminished by intermittent heating. The possibility of the subsequent production of anaphylaxis is an objection to the giving of antitoxin as a prophylactic to ward off diphtheria. Should a child

so immunized subsequently develop the disease more than twelve days after the prophylactic injection, there will be a danger of anaphylactic phenomena showing themselves after the first injection of antitoxin for curative purposes. The anaphylactic symptoms are occasionally very serious, and may even cause death.

Tuberculin and mallein are substances obtained by growing the *Bacillus tuberculosis* and *Bacillus mallei* in glycerine, veal, or beef broth for several weeks, and then filtering off the organisms. Tuberculin is used for diagnostic purposes both in men and cattle, and is now coming largely into use for the treatment of tuberculosis in man. The tuberculin for treatment is derived either from human or bovine sources. Sufficient time has not yet elapsed, since this treatment came into use, to enable us to say whether bovine or human tuberculin has the best curative results. There can be no question, however, that tuberculin injections carefully carried out in suitable cases have considerable effects in raising the resisting power of the body to the toxins produced by the invading bacillus. On the other hand, the effect of tuberculin injections on the disease foci in the body is often disappointing. Mallein is extensively used in veterinary practice for the diagnosis of glanders.

When a patient becomes infected, the germs may multiply so rapidly that the body is completely overcome by the toxins before anti-substances have had time to develop to any extent. In such circumstances the patient dies.

If the patient is able to survive the attack for some days, the infected tissues of his body are as a rule able to completely eradicate the disease, by the generation of an overwhelming amount of anti-substances to the germ in question.

Sometimes a kind of balance is established, wherein sufficient antibodies have been produced to keep the germs in abeyance, but not sufficient to completely destroy them. When this occurs a chronic condition is established, and the patient may go about in moderate health, quite unaware that he is a carrier of the disease, and a source of danger to others who are not so immune.

Now specific therapy has as its object the artificial increase of antibody. Incidentally, it has a secondary object—the maintenance of efficient complement. The artificial production of antibody may be attained in two very different ways: *passive immunity* may be conferred upon the patient with ready-made

antibody, or *active immunity* may be produced by stimulation of the patient to manufacture his own antibody on a larger and more efficient scale than he is already doing. Immunized serum derived from animals (*e.g.*, the horse), which have been immunized by either bacteria or their toxins, is most commonly used to confer passive immunity; active immunity is most commonly produced with bacterial vaccines derived directly from the culture of different organisms. The two methods may be combined in certain diseases.

The protective anti-bacterial substances remain in the system for a considerable time following the inoculation, and by circulating in the blood they render the individual less susceptible to attacks by that particular germ which was injected as a vaccine. The immune substance develops slowly and increases gradually in quantity as the result of successive inoculations, and when once produced it is eliminated slowly from the system, so that the immunity lasts from three months to several years.

A vaccine may be defined as an emulsion of dead germs standardized to a given strength suitable for therapeutic or prophylactic injection. A vaccine can be prepared from any given germ which can be grown artificially in pure culture.

There are now in existence a very large number of different vaccines, made up of such germs as cause typhoid fever, pneumonia, influenza, colds, meningitis, tuberculosis, boils, acne, gonorrhœa, puerperal fever, rheumatism, etc.

Many vaccines contain a single species of germ only; thus a tuberculosis vaccine, or tuberculin, contains only the tubercle bacillus or a product of it.

It is now known that there exist many species of the same germ; thus there are four varieties of pneumococci, and a good pneumococcal vaccine should therefore contain the dead bodies of all the four types. Such a vaccine, consisting of several strains or varieties, is called "*polyvalent*."

Again, many diseases, such as coryza (cold in the head) and bronchitis, are due to an infection with more than one kind of germ. In such conditions it is usual to find the pneumcooccus, the streptococcus, the *Micrococcus catarrhalis*. *Bacillus Friedlander*, *Bacillus septus*, etc. For such complaints a single simple vaccine of one germ alone is not sufficient, and hence it has been found necessary to prepare "*mixed*" or "*compound vaccines*" for such mixed infectious conditions.

Finally, a special vaccine may be prepared from the actual species of germ or germs infecting a given individual. Such a vaccine made specially for a given patient is called an "*autogenous vaccine*."

Anti-variolous vaccine, or vaccine proper, differs from other therapeutic agents of microbial origin in that it is a preparation containing a *living* micro-organism—the specific micro-organism of vaccinia or cow-pox.

There are reasons for believing that large doses of *detoxicated* vaccines, obtained by removing the endotoxin of the bacterial cell, may possess a special value.

The following is a list of diseases in which preventive inoculations are employed:—Anthrax, bubonic plague, chicken cholera, Asiatic cholera, diphtheria, dysentery, glanders, hog cholera, hog erysipelas, hydrophobia, meningitis, pleuro-pneumonia in cattle, pneumonia, influenza, "colds," swine plague, streptococcus infection, symptomatic anthrax or quarter evil, tetanus, tuberculosis, and typhoid fever.

The serum diagnosis of acute specific fevers has attracted much attention, more especially in relation to Malta fever and enteric and paratyphoid fever. Durham and Gruber have shown that whenever the micro-organisms, which are causally associated with these diseases, are brought into contact with the diluted serum or plasma of an animal or a patient who is undergoing, or has recently undergone, an attack of the disease in question, the following succession of phenomena (or some of them) manifest themselves: (1) The bacteria become agglutinated, or clump; (2) the bacteria lose their motility; (3) the clumps of agglutinated bacteria sink to the bottom of the tube, and the culture fluid, which was previously evenly turbid, becomes clarified; (4) the bacteria shrink up into the form of minute spherules; (5) the bacteria are definitely devitalized. This method is now being extended to the diagnosis of other diseases, especially infection with Gaertner's bacillus, *Bacillus pyocyaneus*, and glanders in horses; also to cholera and plague.

Human "Carriers" of Disease.

While it is with regard to the two diseases typhoid fever and diphtheria that the subject of human carriers of infection has been more particularly investigated, the danger has been demon-

strated by many other communicable diseases, embracing dysentery and diarrhœa, cerebro-spinal fever, encephalitis lethargica, acute poliomyelitis, influenza, pneumococcal infections, paratyphoid fever, sleeping sickness, scarlet fever, plague, and tuberculosis. In cholera it has been ascertained that a small percentage of healthy persons may be acute carriers of vibrios (some of which may be non-agglutinating) when the disease is displaying epidemic prevalence, and that from 1 to 2 per cent. of the actual sufferers from cholera may develop into chronic carriers. Carriers may be divided into four groups—namely: (1) Precocious or incubation carriers, but there is little evidence that such carriers, if they exist, exert much influence in the propagation of infections. (2) Contact carriers—*i.e.*, persons who have been in contact with an infectious disease, and carry micro-organisms morphologically identical with those causative of the disease, such micro-organisms not being necessarily virulent, or only slightly virulent, and in some cases reduced to mere saprophytes. The contact carrier often responds to infection by producing recognizable immunity substances in the blood, and he generally throws off the infection in a short time, the outward and visible signs of infection (the symptoms) being absent, or unrecognized. (3) Convalescent carriers, who continue to harbour during convalescence the organisms which caused the illness. (4) Chronic carriers, who harbour infective organisms for long periods after recovery from the disease, periods of infectivity being often only displayed intermittently, with intervening periods of non-infectivity. There are good grounds for concluding that the "chronic carrier" is far more dangerous than the temporary or "acute carrier."

It is not easy to assess the influence of carriers in maintaining the prevalence of disease, for the "missed" cases (thought to be influenza or diarrhœa in typhoid fever, or sore throats, colds, or mumps in diphtheria) cloak the influence of the chronic carrier. While it would seem that, generally speaking, the germs from chronic carriers are leading a sort of saprophytic existence and are not so infective as those associated with acute cases of illness, the cautious view from the standpoint of preventive medicine is to regard all carrier cases as potentially infectious.

In devising means for dealing with the danger of carriers, the first consideration which naturally arises is as to whether it is possible to prevent cases developing into carriers, and failing

this, what are the best practicable means of protecting the community from the danger which they at present involve. Unfortunately, we do not know why the germs of specific disease disappear in some persons and persist in others; and so it is difficult to devise means of preventing individuals from developing into chronic carriers.

Certainly those persons who are about to be discharged from infectious hospitals after suffering from infection which may be carried, should first be examined to see if they are still harbouring infection in the nose, throat, or ear, or excreting it in fæces or urine. So far as the typhoid convalescent is concerned, this is no easy matter, since the examination of the fæces entails a laborious and highly-skilled procedure; and on that account it has been suggested that, since the majority of carrier cases excrete the germ in their urine, and its examination is a comparatively simple matter, urine tests might be adopted in the first place as the routine procedure. This examination might be combined with a Widal blood test, to which about 66 to 75 per cent. of chronic typhoid carriers respond. While such a procedure would fail in a percentage of cases, the routine examination of the fæces prior to discharge from hospitals would also fail in some cases, for the reason that the germs may be only intermittently discharged in the fæces, and therefore may be missed.

The question which next arises is as to whether there are means available of freeing carriers within a reasonable period from the germs which they harbour. Difficult as the certain cure of a diphtheria carrier case is, the enteric fever carrier case is far more so. It is not yet possible to certainly identify all carrier cases of enteric fever, and it is certainly quite impracticable to retain such cases in hospital until they cease to be carriers. While in the bacilluria of convalescence from enteric fever certain urinary antiseptics are useful, in chronic carrier cases of this disease they are of little if any value, and the same may be said of vaccines. In the case of diphtheria carriers, antitoxin exerts no effect upon the persistence of the germ; but the spraying of the nose and throat for several days with a pure culture of *Staphylococcus pyogenes aureus* has proved a limited success—the diphtheria germ slowly disappearing owing to the crowding-out effect of the staphylococcus. But a similar line of treatment in the case of the enteric fever carrier (involving the use of lactic

acid bacilli in intestinal cases) has furnished no encouraging results.

It is impossible to retain a carrier case in hospital, maybe for several years; and the problem of how the community may be safeguarded from the danger of a typhoid carrier is not an easy one. The most that can be done in practice is for the sanitary authority to keep in touch with such cases when they are notified from the hospitals; to impress upon such carriers the necessity for special care with the dejecta, the cleaning of the hands after having attended to the calls of nature, and the disinfection of dirty bed and body linen. They should also be prohibited from playing any part in the handling, preparation, or cooking of food for others. To this end carrier cases should be given detailed instructions, and kept under observation as much as possible, until they cease to be carriers; and in order to ascertain when this occurs, the sanitary authority should take occasional samples of both urine and fæces for bacterioscopic analysis.

The chronic typhoid carrier adds materially to the dangers of the dry system of excretal collection and disposal; and this danger accentuates the need for more adequate protection from flies, and greater care in the final disposal of excretal refuse. Doubtless the typhoid carrier in rural districts would be more dangerous than the urban carrier, were it not for the fact that the greater isolation of his dwelling in rural districts is a circumstance unfavourable for the spread of the disease.

In investigating the origin of sporadic notified cases of disease, an effort should always be made to ascertain whether any other member of the family has previously suffered from the disease in question; and, where the facts warrant it, material for bacteriological examination should be collected from such persons. The possibility of missed cases acting as carriers must also be borne in mind. The liability of a person who has previously suffered from typhoid fever to intermittent attacks of biliary colic would strongly suggest the possibility that he or she was a chronic typhoid carrier. Having regard to experience in this country and elsewhere, it would be a wise precautionary measure to examine the dejecta of all cooks in institutions, likewise of those workers in factories and workshops in which certain forms of food are prepared.

What is *most* desirable is that all convalescents from typhoid

and dysentery should be specially instructed and trained to observe a high standard of personal hygiene before their discharge from hospital; for the dissemination of infection depends mainly on defective personal hygiene.

The control of the spread of epidemics by the isolation of carriers, even where such a measure is at all practicable, is rendered difficult by the continual occurrence of fresh contact carriers, and the intermittent periods which many carriers are subject to, when no infective organisms can be isolated. In institutions, where the numbers to be swabbed are not too large, early, thorough, and repeated swabbing may put an end to an outbreak. But in other circumstances, where the number of individuals to be examined is very large, swabbing and isolation appear to be only capable of flattening the curve of incidence of disease, at the same time prolonging it (see paper on "The Carrier Problem," by Surg. Comm. S. F. Dudley, *Public Health*, December, 1922). The total number of cases in the epidemic is not diminished, but they are spread over a longer interval of time, by the segregation of some of the sources of infection in the shape of the identified carriers.

So far as our knowledge at present extends, chronic carriers are mostly confined to the enteric group of diseases and to diphtheria. In the enteric group the virulent organism takes up its habitat in some focus such as an inflamed gall-bladder, where it becomes entrenched and cut off from the blood supply and defensive forces of the body; whilst in diphtheria an ulcerated patch in the mucous membrane of the nose, tonsils, or pharynx supplies similar conditions for the continued existence of a virulent organism, although the blood of the host may be well furnished with immune substances.

Insect Carriers of Disease.

The possibility of insects carrying pathogenic organisms has been demonstrated in the case of anthrax, plague, trench fever, zymotic diarrhœa and cholera, and less certainly in the case of typhoid fever and Egyptian ophthalmia. Blood-sucking insects may transmit disease directly from the sick to the healthy (*see* Tropical Diseases), and such a mode of transmission is possible in anthrax, septicæmia, pyæmia, erysipelas, leprosy and tuberculosis. The matter is still *sub judice*, but there are good grounds

for the belief that other diseases may occasionally be thus communicated.

The fleas of the Indian and European rat are the intermediaries of the bubonic plague between rats (which are the primary carriers of the disease) and men; and when plague becomes epidemic, the ordinary flea (*Pulex irritans*) and the dog flea may transmit it directly. Fleas are also suspected of carrying leprosy, and the Mediterranean variety of the tropical fever known as kala-azar.

The domestic fly may carry typhoid, dysenteries, infectious diarrhœa, cholera, diphtheria, ophthalmic affections, infantile paralysis, tuberculosis, and leprosy. All these diseases are of bacterial origin, and hence transmissible by contact, and some of them by the fly infection of food. One small variety of fly which plays a part in the transmission of sand-fly fever passes easily through ordinary mosquito netting.

Of the diseases borne by lice, typhus, relapsing fever, and trench fever are the chief; the first two are hereditary in lice, and are often conveyed by the crushing and rubbing of the louse's body into some cut or abrasion. Except in typhus—which is carried by lice *alone*—the actual bite of the louse is of little account, but the victim's scratching and rubbing are important factors in the spread of disease. The bacillus of plague has also been found in lice feeding on plague patients, but there is no evidence to show that the parasite is of importance in that connection. Many skin troubles are also initiated by lice, which in extreme cases may lead on to death by blood poisoning. The problem of destruction resolves itself into (*a*) the cleansing of the lousy person—preferably with undiluted paraffin emulsion, the customary precautions as to removal of hair being observed in severe cases; and (*b*) the destruction of insects and eggs in clothing, bedding, etc., by baking or steaming. All lice and nits can be killed by half an hour's exposure (dry heat) at a temperature of 50° C.

It has been demonstrated beyond doubt that the mosquito is the means of conveying the malarial parasite, the embryo *Filaria sanguinis hominis*, and the infection of yellow fever from one individual to another.

Insects, moreover, may transport the eggs of animal parasites (*Tænia solium*, *Trichocephalus dispar*, *Ascaris lumbricoides*, etc.), and deposit them on food.

Insect-borne diseases cannot be controlled effectively until the entomologist, carrying on his work from the biological standpoint, has provided the data necessary to determine the insect vector concerned, the critical point in its life-cycle when it can successfully be attacked, and the method of reduction best suited to the various conditions under which it exists in different parts of the world.

Communicable Diseases.

Small-pox and Vaccination.

The incubation period of small-pox is nearly always twelve days, but may vary from nine to fifteen. When the virus has been inoculated, the incubation is said to be shorter—only seven or eight days. The incubation period of *variola nigra* is said to be only six or seven days. Small-pox is probably communicable from the earliest appearance of the symptoms, and the ordinary duration of infectiveness is from three to four weeks. The virus is contained in the mouth and throat secretions of the patient and in the skin eruptions, and is capable of being conveyed for considerable distances through the air in the dried epithelial scales and pus cells from the crusted pocks.

A varioloid disease, a variant of true small-pox, which has been named *alastrim*, occurred as a small outbreak at Cambridge in 1903, and in the summer of 1919 in various localities on the borders of Norfolk and Suffolk. A report on the latter was made by Dr. S. Monckton Copeman for the Ministry of Health (Annual Report of the Chief Medical Officer, 1919-20). A similar disease prevailed in Trinidad in 1902, and has been recorded in Brazil and in South Africa, where it is known as Amaas.

Alastrim, as observed in the Eastern Counties in 1919, differs in its symptoms from small-pox in the following particulars: The eruption develops as a rule on the chest and abdomen before appearing on the face; it comes out in successive crops, like chicken-pox, extending in some instances over a considerable number of days; severe lumbar pain is usually absent, but gastric distress, not infrequently resulting in vomiting, is a noteworthy symptom. The vesicles are dome-shaped, not umbilicated, and they are unilocular, but do not collapse when pricked like chicken-pox vesicles. The stage of pustulation is unaccom-

panied by increase of temperature. The mortality rate is low—about 0·5 per cent. Vaccination, unless recent, does not appear to afford as efficient protection as in the case of small-pox, whilst it has proved possible to revaccinate a case of alastrim successfully during the convalescent period.

Although alastrim as seen in this country is recognizable as a distinct variant of small-pox in the earlier cases of an outbreak, Dr. Copeman notes that the later cases tend to present symptoms of greater severity, and the general course of the disease tends to present fewer abnormal features in relation to small-pox than the earlier cases did. In fact, in this country acclimatization and human passage may modify the virus in the direction of true small-pox.

The exceptional incidence of small-pox in the immediate neighbourhood of some small-pox hospitals, in which were treated during epidemic periods large numbers of cases, serves to demonstrate that these hospitals are liable to become centres of infection to the surrounding neighbourhood. Whether small-pox in these cases is transmitted aerially or by personal communication has been the subject of much controversy, as the faulty administration of the hospital may have allowed the transmission of small-pox in the persons of the hospital staff, or of visitors to the hospital.

Dr. Savill (Warrington outbreak, 1892-93) and others have considered that there are so many agencies at work for the conveyance of infection by human means (more especially in the vicinities of the hospitals), that the hypothesis of aerial convection is unnecessary. That a small-pox hospital in a poor and crowded locality may be, and usually is, a source of infection to the surrounding neighbourhood is not denied; but the incomings and outgoings of the staff, the calls of tradesmen and friends of the patients, and the bringing of the patients to the hospitals, are all dangers which of necessity become intensified as the centre is approached, and may in themselves account for this circumstance.

One consideration which causes many to doubt the correctness of the aerial convection theory is the immunity from attack constantly observed in the large numbers of presumably susceptible individuals living near small-pox hospitals, and the circumstance that in a number of instances no such special incidence of attack has been observed. The late Sir Henry

Power's views on aerial convection are thought by many to be adequately explained by the possibilities of direct or mediate infection from the hospital.

A Local Government Board circular on "The Provision of Isolation Hospital Accommodation by Local Authorities" has, with a view to lessening the risk of infection from small-pox hospitals, laid down the rule that a local authority should not contemplate the erection of a small-pox hospital—first, on any site where it would have within a quarter of a mile of it as a centre, either a hospital, whether for infectious diseases or not, or a workhouse, or any similar establishment, or a population of 150 to 200 persons; and secondly, on any site where it would have within half a mile of it as a centre, a population of 500 to 600 persons, whether in one or more institutions, or in dwelling-houses. Cases in which there is any considerable collection of inhabitants just beyond the half-mile zone should, says the circular, "always call for special consideration."

The contagion clings to infected clothing, bedding, and furniture, and is at times communicated by means of these infected articles, but is probably more often conveyed by contact with a person actually suffering.

Like many other specific infectious diseases, small-pox has a special seasonal prevalence (see fig. 78). From observations covering a long period of years, it can be shown that the average London mortality is greatest during the first six months of the year, rising to a maximum towards the end of May and falling through June, until it descends below the mean line, where it fluctuates during the last six months, to again rise in December or January.

Small-pox is a disease of every climate and every race, and attacks all ages and both sexes unprotected by a previous attack or by vaccination. In this country, however, it causes a somewhat higher death-rate amongst males than amongst females, which indicates either a greater susceptibility to attack on the part of males, or a greater chance of an attack proving fatal in their case. Thus, the average death-rate for males at all ages in England during the years 1854-87 was 0·183 per 1,000 living; whilst the death-rate for females at all ages was only 0·148 per 1,000 living. It arises solely from the contagion of a previous case, and although its severity may be intensified by uncleanly and overcrowded houses and insanitary surroundings, as is the

case with all infectious diseases, it cannot be originated by any such conditions. It is probable that during epidemic periods small-pox is very frequently spread by the number of mild and

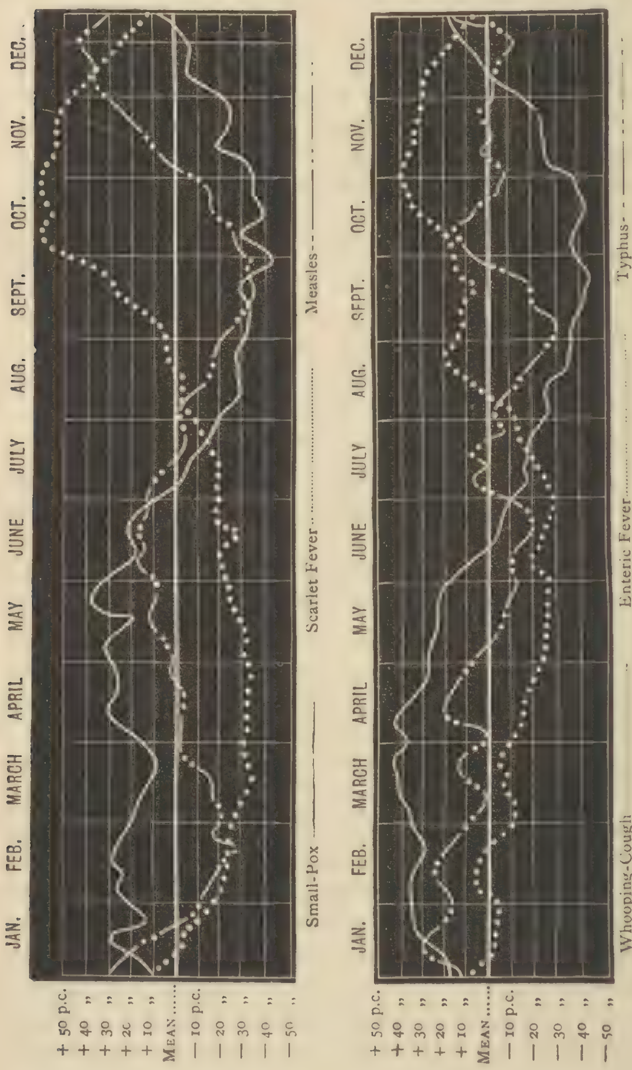


FIG. 78.

The curves represent the average death-rates in corresponding weeks of a period of years, calculated in percentages of the mean weekly death-rate of the whole period (after Buchan and Mitchell).

not easily recognizable cases of the modified disease in vaccinated persons, and the failure to distinguish chicken-pox from this type. The virus from such mild forms is capable of imparting

a very virulent form to unvaccinated persons, and the same holds true of nearly all infectious diseases.

Previous to the discovery by Jenner, towards the end of the eighteenth century, of the protection afforded by the inoculation of cow-pox lymph against attacks of small-pox, small-pox was a disease from which few escaped. From 1750 to 1800, small-pox caused nearly one-tenth of the total number of deaths (96 out of every 1,000 deaths from all causes), and in epidemic years—1796, for example—this fatality was occasionally nearly doubled. So universal was the disease, and so frightful its disfiguring effects and the risk of loss of sight, that the practice of inoculation, introduced originally from Constantinople by Lady Mary Montagu, became very general during the latter half of the eighteenth century. The fatality of the disease so imparted was found to be much less than that of natural small-pox, 2 or 3 per cent. of the cases ending fatally instead of 20 or 30 per cent.; but the infection was thereby enormously multiplied all over the country, and the epidemics became more frequent than ever.

Jenner published the result of his researches in 1798, and since that time vaccination has made steady progress through all classes of the population, with the result of gradually diminishing the frequency of epidemics, the severity of the disease, its incidence on the population, and its death-rate. In 1838 gratuitous vaccination was provided, and in 1854 vaccination became compulsory for all infants above the age of three months; but it was not until 1871 that Boards of Guardians were obliged to appoint public vaccinators for their districts. From 1838 to 1853 the annual death-rate from small-pox in England and Wales averaged 0·42 per 1,000 persons living; but during the past twenty years the average is about 1 per million. At the same time the proportion of small-pox deaths to deaths from all causes has fallen gradually from nearly 100 per 1,000 (or $\frac{1}{10}$) in the eighteenth century to an average of about 10 per 1,000 (or $\frac{1}{100}$) from the year of compulsory vaccination to the present time. The average death-rate from small-pox in the eighteenth century was probably not less than 3 or 4 per 1,000. During the ten years 1911-1920 the average death-rate in England was practically nil, notwithstanding the increased facilities for the spread of the disease resulting from the greater crowding on area of the population during recent years.

MEAN ANNUAL DEATH-RATES FROM SMALL-POX AT SUCCESSIVE LIFE PERIODS PER MILLION LIVING, AT EACH SUCH LIFE PERIOD.

	All ages.	0-5.	5-10.	10-15.	15-25.	25-45.	45 and upwards.
I. Vaccination optional (1847-53)	305	1617	337	94	109	66	22
II. Vaccination obligatory, but not efficiently enforced (1854-71)	223	817	243	88	163	131	52
III. Vaccination better enforced by vaccination officers (1872-91)	89	177	95	54	97	86	38
IV. 1891-1900 ..	13	29	10	3	8	17	10
V. 1901-1905 ..	25	—	—	—	—	—	—
VI. 1906-1910 ..	0	—	—	—	—	—	—

Compulsory vaccination in infancy has saved the lives of an enormous number of children, who formerly died of small-pox, whilst the death-rate from small-pox at all ages has of recent years greatly diminished. The mortality from small-pox amongst infants under one year of age is largely due to deaths of infants from this disease before vaccination has been performed. After the age of fifteen the protective influence of the primary vaccination has to a large extent disappeared; and unprotected adults form a larger proportion of the population than in the earlier periods, when an attack of small-pox in childhood was far more common and, as a rule, gave immunity from the disease for the rest of life.

It was at first thought that one vaccination afforded indefinite protection to the individual against small-pox. This is now known not to be the case—with regard to infantile vaccination, at least. In the first place, the efficacy of vaccination depends largely upon the efficiency of the operation and the number and character of the resulting scars. Secondly, the protective influence wears away with the lapse of time, and revaccination at or before the age of puberty is a measure the necessity of which is beyond question. Calf lymph and that from a vaccine vesicle of the eighth day from a healthy infant, if used perfectly fresh, are probably capable of giving equally good results, as regards protection.

The protective effects of vaccination have been studied chiefly in relation to the fatality and severity of the disease in the vaccinated and unvaccinated. But this, it must be remembered, is only one side of the question, and the relative incidence of the disease on these two classes is deserving of study. The exact proportion of unvaccinated to vaccinated in the community is not definitely known, but taking it at its highest figure, the unvaccinated probably do not form more than 15 per cent. of the total population. On the other hand, the unvaccinated certainly form not less than 30 per cent. of the cases treated in small-pox hospitals, and the proportion of severe and hæmorrhagic cases is far larger amongst the unvaccinated than the vaccinated.

In the year 1919 primary vaccinations in infancy were only 40·6 per cent. of the births registered in England and Wales, and the exemptions granted on account of conscientious objection by parents to vaccination were 40·1 per cent. of the births. In the ten years 1910-1919, allowance being made for those who have died, there remain 2½ million children under twelve years of age who are legally exempted from examination. A further ¼ million unvaccinated children are added annually to this number, so that in 1922 the number of unvaccinated children under twelve years was about 3 millions.

The fatality of the disease in the two classes is illustrated in the diagram, founded on figures supplied by Dr. Collie (for the two epidemic years of 1871 and 1881), of cases treated in London small-pox hospitals (fig. 79). Under fifteen years of age and over fifteen years the mortality per cent. of cases in the unvaccinated is nearly identical, viz., 37 or 38 per cent.; whilst under fifteen the influence of the number and character of the scars in the vaccinated is seen to be of not nearly so much importance as over fifteen. The evanescence of the protective influence of primary vaccination after the age of fifteen is thus well exhibited; for whereas one or more bad marks reduce the mortality to 4 per cent. under fifteen, over fifteen the mortality of cases with one or more bad marks is 10 per cent. Taking nearly 7,000 cases observed in recent years, the Royal Commission on Small-pox and Vaccination found that the small-pox fatality rate in persons with one mark was 6·2 per cent.; with two marks, 5·8 per cent.; with three marks, 3·7 per cent.; and with four marks, 2·2 per cent.

Revaccination at puberty, if properly performed, confers a very high degree of immunity from small-pox for the remainder of life; and if by any chance a revaccinated person should acquire small-pox, the disease generally assumes its mildest type. In Prussia since the year 1874, when vaccination and revaccination became compulsory, the death-rate from small-pox has been reduced to one-tenth of its former rate, viz., from 0·24 per 1,000 to 0·02 per 1,000; and it is stated that in the Prussian Army there had not been a single death from small-pox from 1874 to 1914.

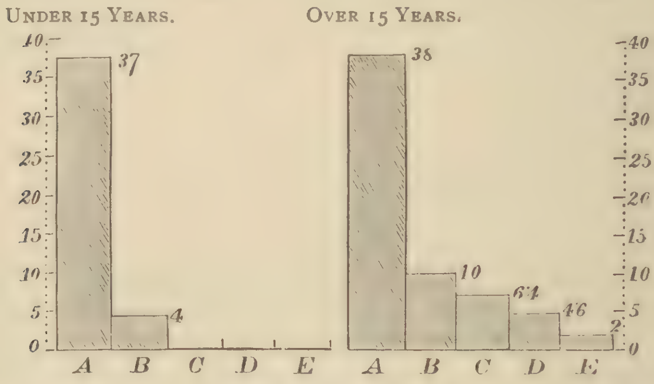


FIG. 79.—SMALL-POX EPIDEMICS, 1871, 1881; MORTALITY PER CENT. IN FEVER HOSPITALS (LONDON).

−15	+15	
(386)	(174)	A = unvaccinated.
(222)	(483)	B = one or more bad marks.
(76)	(141)	C = one good mark.
(44)	(151)	D = two good marks.
(70)	(100)	E = three good marks.

In Germany, with a population of over 60,000,000, surrounded on three sides by badly vaccinated countries, small-pox has been almost stamped out, and during the ten years 1885-95, 79 per cent. of the few cases which occurred were resident on the frontiers; whereas in Austria and Belgium, where vaccination is not compulsory, the death-rates from small-pox are more than twenty-fold as great. The great immunity which Germany enjoys is due to the fact that in that country vaccination and revaccination are compulsory, and, as a consequence, in Berlin, with a population of 2,000,000, twelve hospital beds reserved for small-pox have been found for many years to suffice for all requirements. The compulsory vaccination age is the second

year of life, and it is significant to note that in 1886-90 more than two-fifths of the few deaths that occurred from small-pox were under two years of age. Revaccination is performed in Germany at the end of the period of compulsory school attendance, and every recruit is revaccinated on joining the army. In France primary vaccination must be performed between three and twelve months of age, and revaccination between ten and eleven years of age, and again between twenty and twenty-one.

Dr. Barry found from the facts of the Sheffield epidemic of 1887-88 that unvaccinated children under ten years are twenty times more liable to attack than the vaccinated, and unvaccinated persons over ten are five times more liable; and in unvaccinated children under ten the attack is twenty-two times more likely to be fatal than among the vaccinated, while in unvaccinated persons over ten the risk of an attack proving fatal is eleven times as great. Therefore, during small-pox prevalence, an unvaccinated child under ten is 440 times more liable to die than a vaccinated one, and an unvaccinated person over ten is fifty-five times more likely to die than a vaccinated one. Moreover, 17·2 per cent. of the attacks were severe among those vaccinated, while among the unvaccinated 81 per cent. were severe; and in children under ten years 9 per cent. of the attacks were severe among those vaccinated, and 78 per cent. among those unvaccinated.

In houses invaded by small-pox, in the course of an outbreak, not nearly so many of the vaccinated inmates are attacked as of the unvaccinated, in proportion to their numbers. Taking children under ten in invaded houses, in Dewsbury, 10·2 per cent. of the vaccinated were attacked, and 50·8 per cent. of the unvaccinated; in Leicester, 2·5 per cent. of the vaccinated, and 35 per cent. of the unvaccinated; and in Gloucester, 8·8 per cent. of the vaccinated, and 46·3 per cent. of the unvaccinated.

It is the custom for antivaccinators to attribute the reduction in small-pox incidence to improved sanitation; but improved sanitation will not account for—(1) The fact that small-pox mortality has been transferred from childhood to the later periods of life since vaccination has been introduced; whereas in Germany, where vaccination is not compulsory till the second year of age, over 40 per cent. of all the small-pox mortality occurs under two years of age. (2) The immunity enjoyed by revaccinated postmen and nurses. The revaccinated nurses at the

Leicester Small-pox Hospital escaped, while those who refused revaccination were attacked. (3) That the disease passes by the vaccinated children, but attacks the unvaccinated living *in the same house*, as in Dewsbury, Leicester, and Gloucester. (4) The lessened fatality among the vaccinated if attacked. (5) That those with three or four vaccination marks are less liable to a fatal attack than those with one or two. (6) The great immunity which Germany enjoys, even as compared with Great Britain. Finally, the disease has never been shown to be caused, directly or indirectly, by any insanitary condition.

The isolation of small-pox cases in hospitals is a useful auxiliary to vaccination, but it is not a sufficient substitute for it, owing to the inevitable failure to secure isolation, in all cases, with the necessary thoroughness and promptness. Such failure results from parents not observing the early symptoms of the illness, the neglect to call in a doctor, the difficulties of diagnosis, the delays in removal, the probable inadequacy of the hospital accommodation during an epidemic, and the possible inefficiency of the disinfection of infected articles.

The operation of vaccination, if properly performed with clear fresh lymph, does not impart any other disease but vaccinia. But among the maladies which have been attributed to vaccination are: syphilis, erysipelas, diarrhœa, tabes mesenterica and scrofula, bronchitis, cancer, leprosy, and many forms of skin disease.

Vaccino-syphilis has, however, in the past happened so rarely as to constitute it a clinical curiosity. With the general introduction of calf lymph it will disappear altogether, as calves are not subject to syphilis. Vaccino-syphilis has often been confounded with a congenital syphilis, latent until lighted up by vaccination. The acquired syphilitic rash, however, appears at the earliest from fifty to ninety days after vaccination, and in every case a chancre forms at the site of vaccination. The syphilitic chancre is limited to one or two points of inoculation, inflammation is slight, loss of substance is superficial, and the parchment induration is typical (Fournier). That the increase in infantile syphilis is due to vaccination, as asserted by the antivaccinators, is disproved by the fact that whereas in England and Wales, with vaccination generally enforced, the increase in the infant mortality from syphilis between the two periods 1863-67 and 1883-87 was 24·7 per cent., in Leicester, where vaccina-

tion has been neglected, the increase was no less than 69·3 per cent.

As to vaccino-erysipelas, this disease has doubtless often resulted from vaccination, either directly from the failure to take due precautions as regards cleanliness at the time of the operation, or, indirectly, from exposure to dirt and insanitary conditions in the home of the recently vaccinated infant. The frequency of occurrence of vaccino-erysipelas is, however, greatly exaggerated by the antivaccinators. In the two periods already mentioned the infant mortality from erysipelas in England and Wales *decreased* by 16·7 per cent., whilst in Leicester, with neglected vaccination, there was an increase of 41·5 per cent. Similarly, diarrhœa and bronchitis have increased among the unvaccinated infants of Leicester more than in England and Wales as a whole, a fact which proves the fallacy of attributing any increase to vaccination.

With regard to cancer, the Royal Commission on Vaccination concluded:—" There is not a shadow of evidence to connect the increase with the practice of vaccination, whilst there is . . . evidence pointing the other way." The same remarks are applicable to the alleged spread of leprosy by vaccination. There is no evidence, moreover, that tuberculosis has ever been inoculated by vaccination, and attempts to thus inoculate the skin of guinea-pigs with lymph from tuberculous patients have uniformly failed. That the disease may be transmitted through the medium of animal (calf) lymph is a groundless fear, which has been encouraged by antivaccinators. Such a case has never yet been reported, although animal vaccine has been in use for many years, more especially on the Continent.

Certain rashes have doubtless been produced, and not infrequently, by vaccination. Even when vaccine quite pure and free from other virus is inoculated, eruptions of urticaria, erythema, lichen, purpura, and later, as sequelæ of vaccination, eczema, psoriasis, and pemphigus, have been observed. When, however, the vaccine has not been pure, impetigo contagiosa, syphilis (very rare), erysipelas, cellulitis, pyæmia, or local gangrene have occasionally resulted from the inoculation of the lymph.

It is the intention of the Government to limit vaccination and revaccination in the future, so far as is possible, to vaccination with glycerinated or chloroformed calf lymph. The object is to reduce the risks of conveying " vaccinal " diseases, which

were sometimes incidental to "arm-to-arm" vaccination. The glycerine or chloroform serves to preserve the lymph, without in any way interfering with its activity, and it destroys extraneous organisms (even, in time, the *Bacillus tuberculosis*). The presence of a little blood in the lymph is quite harmless, and the danger of imparting disease appears to be absolutely avoided by the use of glycerinated calf lymph.

The calves used are carefully watched, their past history is inquired into, they are slaughtered after use, and a post-mortem examination is made, whilst in some countries the calf is tested with tuberculin before inoculation with vaccine lymph. These precautions are taken notwithstanding the great rarity of tuberculosis in young bovines. The age of the calf, its general health and nutrition, and even the season of the year, affect the quality of the lymph collected.

In Paris the lymph is diluted with an equal bulk of glycerine; in Brussels twice the bulk of glycerine is added; in England five to eight times its bulk of 40 or 50 per cent. pure glycerine in distilled water is added; and in Berlin a solution of equal parts of glycerine and boiled water is added to the epithelial pulp scraped from the vaccine vesicles, in the proportion of 14 parts of the solution to 1 of the pulp.

In the process of chloroforming, a mixture of chloroform vapour and air is passed through the vaccine emulsion. The vaccine so treated can be issued for vaccination purposes after an interval of seventeen days, which is a shorter period than is required in the case of glycerinated lymph.

It is probable that if vaccination is performed on a person who has already contracted small-pox, within forty-eight hours of the exposure to contagion, vaccinia ensues and small-pox is avoided. But if performed at a later date small-pox is contracted, modified if within three days, but unmodified if later, with vaccinia possibly running its own course at the same time.

Under the Public Health (Small-pox Prevention) Regulations, 1917, a Medical Officer of Health may, on the occurrence of any case of small-pox, and where the circumstances in his opinion so require and permit, perform vaccination or revaccination on any person who has come in contact with the infection, and is willing to be vaccinated, and without charge to the said person. The Medical Officer of Health must keep a record of every vaccination or revaccination, giving the date, name, age, address

of each person, the result, and the source of the lymph used, with the official reference number, if obtained from the national vaccine establishment.

The point has been recently raised that as small-pox is now comparatively a rare disease in this country, and that as modern methods of public health administration are generally effective in preventing any widespread diffusion from isolated cases, it is no longer necessary to secure compulsory vaccination in infancy. It is also said that the presence in a population of large numbers of persons who are partially protected only by a previous vaccination, leads to the occurrence of numerous cases of modified small-pox, which are difficult to diagnose, with the result that cases of true small-pox are missed, and there is a danger to the public from this very fact. It is argued that if all cases of small-pox occurring in a population were unmodified, owing to the unprotected condition of the people, small-pox would be easy to diagnose, and but few cases would ever be missed. It is suggested that vaccination need only be resorted to for contacts, who had been exposed to infection, or be made available for the general population, when the measures of control had failed, and an epidemic was threatening.

Those who still favour compulsory vaccination in infancy point out that it is not only the cases of small-pox modified by previous vaccination that cause errors in diagnosis, but also the mild cases of the unmodified disease, which would be as numerous as heretofore; and that there is, in consequence, no guarantee that errors in diagnosis would be very materially reduced if the population were entirely unprotected by vaccination. Moreover, if compulsory vaccination were abolished now, it would be many years before those who have been at some time vaccinated died out; and in any case large numbers of people who believe in vaccination will still have their children vaccinated soon after birth. On general grounds there appears to be reason to believe that small-pox is less likely to become epidemic in a partially protected community than in an entirely unprotected one; and that it would be very unwise in the present state of our knowledge to discard a prophylactic measure, which may be in many respects defective, but is still better than no prophylaxis at all.

Considerable evidence has now been accumulated in support of the view that cow-pox is human variola modified by its occur-

rence in the cow. Klein has shown that when lymph from the vesicles of a human small-pox case is inoculated into a calf, very little local result is produced, but that if material from the local lesion is taken on the fifth day, and inoculated into another calf, and this process is continued until four calves have been inoculated, the material from the fourth calf (four removes from the small-pox patient) might with safety be transferred to the human subject, with the production of typical vaccinia. The lymph from the vaccine vesicles, so produced in the human subject, caused, alike on inoculation into the bovine or the human subject, typical vaccinia.

Whatever the original cause of cow-pox in the bovine species, it seems certain that the disease is now transmitted directly from animal to animal, and that its origin from human small-pox is an event of very rare occurrence, if it ever happens.

Small-pox may be confounded with measles and scarlet fever, owing to scarlatiniform or morbilliform rashes occasionally preceding the true variolous eruption; and the latter may be mistaken for chicken-pox, acne, impetigo, eczema, syphilis, and typhus. A failure to recognize the true nature of the disease is often responsible for subsequent spread in epidemic form.

The chief preventive measures to be taken on the occurrence of a case of small-pox are:—(1) The removal of the patient to an isolation hospital; (2) the disinfection of infected rooms and clothing; (3) the revaccination of the other inmates of the house; (4) either the quarantining of those contacts for fourteen days who have had personal communication with the patient during his illness, or a daily medical inspection with the object of promptly isolating them on the appearance of the initial symptoms; (5) the notification of schools attended by children in the house.

Having regard to the fact that in the event of an outbreak of small-pox the Sanitary Authority has to direct all the other administrative measures taken to stamp out the disease, it is an anomaly that the important measure of vaccination and re-vaccination should not also be under its direct control.

It is, moreover, desirable that legislation should empower the infliction of a penalty for withholding the fullest information, or for giving false information, when sanitary officials are endeavouring to trace the origin of, or to otherwise deal with, the infection.

With reference to the quarantining of contacts the Local Government Board, in a circular issued in 1902, advised as follows:—

If, on a dwelling becoming invaded by small-pox, the actual patients are at once removed to hospital, the dwelling and all articles in it that have been exposed to infection, including the clothes worn by the other inmates, properly disinfected, and the other inmates of the house are immediately revaccinated or vaccinated (as the case may be), there is no material advantage to be gained by keeping these other inmates at home. They are not likely to infect other people unless they themselves develop small-pox; and all that is required is to keep such persons under medical observation for a fortnight, and particularly to examine them carefully day by day towards the end of the second week from their exposure to infection, in order to ascertain whether any of them are developing small-pox. If none of them do so by the beginning of the third week from exposure, the revaccination (or vaccination) to which they were at once submitted on the occurrence of the first case in the invaded house should secure them from attack by the disease.

The Board consider that in ordinary circumstances the course of action indicated above is the correct one. Occasions, however, may arise in which additional precautions may be necessary; as, for example, when laundries are in question, or where the business or habits of the inmates of an invaded house are such as to make it difficult for proper medical observation of them to be maintained. In exceptional cases of this kind, in which a Borough Council are advised by their Medical Officer of Health that in the special circumstances it is essential that the inmates should remain in their own houses, the Board would be prepared to sanction a reasonable expenditure in securing such a result.

Many outbreaks of small-pox have been traced to tramps—a class of people who are practically exempt from any sort of sanitary supervision. To obviate this danger, the local authority should be empowered to require a medical examination of all persons entering common lodging-houses and casual wards, and to enforce the temporary detention of all small-pox "contacts" of the vagrant class.

Scarlet Fever.

This is a specific infectious disease like small-pox, its propagation being dependent upon a specific contagium derived from a previous case of the disease. The incubation period varies from a few hours to eight days, and is usually from twenty-four to seventy-two hours. Infection is given off in the throat secretions and from the skin of the patient during the whole period of

illness, but the acute stage of the fever, when the sore throat and rash are most highly developed, is doubtless the most infectious, and not the desquamative stage, as once generally supposed. The contagion is liable to render the clothes, bedding, and furniture of the sick-room infective, but is not capable of diffusion and dissemination through the air without loss of virulence, as the small-pox contagium appears to be. Schools play an important part in disseminating infection, and many milk-borne outbreaks of this disease have been recorded.

The usual duration of infectiveness in scarlet fever is from six to eight weeks, lasting throughout convalescence, and possibly prolonged by the occurrence of nasal or oral discharges, etc. In large towns scarlet fever epidemics tend to recur every few years, as a fresh series of susceptible children accumulates in the community.

There can be no doubt that scarlet fever is disseminated to a considerable, but unknown, extent by the occurrence of mild and unrecognized (missed) cases, possibly also by carriers, who have been in contact with cases and harbour the specific germs, but are unaffected thereby. If scarlet fever were only spread by the recognized and notified cases, the effect of isolation methods in hospitals and at home must have been far more productive of results in reducing the prevalence of the disease than is now the case. Notwithstanding compulsory notification and isolation, the general prevalence of scarlet fever in this country has not been greatly reduced, as compared with the years before such prophylactic measures were commonly undertaken. The lowered death-rate from scarlet fever is very largely due to the mild type now prevailing, and not to any lessened incidence on the population at large. The proportion of deaths to attacks is now less than half of what prevailed thirty or forty years ago.

Scarlet fever is more especially a disease of childhood, the incidence being greatest at five and six years of age. The influence of age and sex upon the incidence and fatality of the disease may be thus summarized:—

The mortality from scarlet fever is greatest in the fourth year of life, and after this diminishes with age, at first slowly and afterwards rapidly, owing to the diminishing risk in successive age periods of an attack, should it occur, proving fatal. The liability to attack is small in the first year of life, increases to a maximum in the fourth or fifth year, and then becomes rapidly

smaller and smaller with the advance of years. The female sex throughout life is more liable to scarlet fever than the male sex; but the attacks in males, though fewer, are more likely to terminate fatally.

The proportion of fatal cases to attacks of scarlet fever cannot be accurately stated, owing to the large number of unrecognized cases of very mild type, often without skin eruption, and with very little desquamation. The case mortality (proportion of deaths to attacks) is now not greater than 1 per cent. The mortality of well-marked cases, such as those admitted into the Metropolitan fever hospitals, is now under 2 per cent.

For the year 1921 the death-rate from scarlet fever per 1,000 living at all ages in England and Wales was 0·03. During the ten years 1871-80, the average death-rate in England and Wales from scarlet fever was 0·7 per 1,000 living at all ages.

Scarlet fever is a disease from which very many people altogether escape. The importance of saving young children from attacks of scarlet fever has been well expressed by Dr. Whitelegge:—

"In shielding a child against infection during the first few years of life there is a double gain: every year of escape from scarlet fever renders him less and less susceptible, until finally he becomes almost insusceptible; and, secondly, even if he should ultimately take the disease, every year that the attack is deferred reduces the danger to life which it brings. In other words, attacks of scarlet fever become both less severe and less frequent with every year of age after the fifth. Up to the fifth year the liability is less (than in the fifth year), but the risk of life in case of attack is very great."

The same reasoning applies with almost equal force to measles, whooping cough, and the other infectious complaints of childhood.

Overcrowding and insanitary conditions in houses tend to aggravate the severity of scarlet fever attacks, and to aid in their dissemination, but can have no influence *per se* in originating an outbreak.

Scarlet fever is most prevalent and most fatal in the months of October and November. Two curves may be formed, one expressing the deaths as percentages of the average mortality throughout the year (fig. 78), the other expressing the number of cases as percentages of the average of cases throughout the

year. These curves correspond very closely, but Dr. Whitelegge has noted that the mortality curve rises less and falls less above and below the mean than the case curve, which would imply that when most prevalent scarlet fever is least fatal, and *vice versa*. There is a strong probability in favour of this view, as the number of mild cases is usually greatest when scarlet fever is most prevalent.

It sometimes happens that a patient discharged from hospital, apparently free from infection, is the means of communicating the disease to another member of the family on his return home. These "return cases," which, however, in most large communities form less than 3 per cent. of the total cases treated in hospital, have been explained in many ways. Doubtless they are sometimes examples of mere coincidence; at others they may result from: (1) the non-disinfection of articles of clothing, books, or toys, which have been used by the patient prior to removal to hospital, and produced again on the patient's return home; (2) carelessness on the part of hospital officials in prematurely discharging patients with unhealthy throats, nose and ear discharges, etc., or in not sufficiently bathing the patients and shampooing the head prior to discharge; (3) the reappearance of desquamation (?), or infectious discharges after dismissal of the patient from hospital in an apparently healthy condition; (4) the conveyance of the infection in the lungs of recently discharged patients (?).

The entire prevention of such "return cases," even by the exercise of every possible care, seems impossible in practice; but their number would doubtless be reduced if parents could and would observe the precaution of keeping the child apart from other children for at least one week after returning home from hospital. The provision of special convalescent wards, of smaller wards involving less aggregation of the patients, and the greater development of bacteriological assistance, are further measures that are recommended.

The value of the hospital isolation of scarlet fever has been called in question, as those towns where the largest proportion of cases are thus isolated cannot be shown, statistically, to have suffered less from scarlet fever than others where little or no such isolation has been provided. This is largely due to the fact that the value of the hospital isolation of this disease has been discounted by the frequent failure to recognize cases of

infection in a sufficiently early stage—more especially during the recent years of attenuated virulence of the disease. But hospitals are only one of the factors which determine the prevalence of infectious diseases, and the other factors concerned may conceivably favour those towns where hospital isolation has been comparatively little practised; besides, we have no means of knowing what would have happened in those towns where a large proportion of cases are isolated if no hospital isolation provision had existed. Moreover, the different wave lengths of epidemics, the variable intervals between local epidemics, and the different proportions of those comprised within the susceptible age periods in the towns compared, may make the comparison a misleading one.

Certainly scarlet fever is now a very mild disease, and a large amount of money is spent upon its isolation to the possible prejudice of other far more fatal diseases; and these facts warrant some discrimination in the selection of the cases which should be admitted to hospital—the cases selected being limited to those who cannot possibly be isolated at home owing to special circumstances, including interference with the wage-earning or educational needs of the other members of the household. It is only reasonable to maintain that hospital isolation of the disease must have done something to reduce the number of those who would otherwise have been attacked, and that skilled hospital treatment must have been beneficial to the sufferers; but there is little to be said for the indiscriminate isolation practised in London and elsewhere, to the exclusion of severe cases of measles and whooping cough. In conclusion, it must be borne in mind that the experience of the past shows that the infection of scarlet fever has exhibited secular periods of attenuation and renewed virulence; and the disease may possibly in a few years again assume the severer type, which demands an extensive provision of hospital isolation.

Measles.

A specific infectious fever, with an incubation period generally of nine to twelve days, but which may be as short as six days and as long as fourteen. The contagion is given off from the secretions of the nose, throat, lungs, and possibly from the skin of the patient during the whole period of illness. The catarrhal stage preceding eruption is especially infectious, and at this stage

it is impossible to diagnose the complaint with certainty. It is for this reason that epidemics of measles are so difficult to control. The infection is not widely diffusible in the air, but may cling to clothes and garments for a short time.

Measles is a disease of infancy and early childhood, and is very fatal to young children, frequently owing to pulmonary complications and sequelæ. Adults unprotected by a previous attack are also susceptible, but the disease is so universal in this country that few children escape from it. The mortality from measles is greatest under three years of age; the highest death-rate is reached in the second year of life; after five years of age the mortality is enormously diminished. Over 90 per cent. of the total deaths are among children under five. During the seven years ending 1921 the average death-rate at all ages in England and Wales from measles was 0·22 per 1,000 living at all ages. In the ten years 1871-80, the average death-rate in England from measles was 0·38 per 1,000 living at all ages; and in the decennium 1861-70 it was 0·44. Both sexes are equally liable to attack, and the case mortality is about the same for both. In this disease the case mortality is greatly affected by overcrowding and insanitary conditions generally. In the overcrowded houses of the poor, amongst badly nurtured children, the proportion of deaths to attacks may be as much as 10 per cent., and is, no doubt, intensified by the neglect of the parents to provide suitable warmth and nourishment for the sufferers from a disease which they think of little moment. In healthy houses, well-nourished children almost invariably make a good recovery. The cases admitted to the Metropolitan Asylums Board Hospitals in 1915 showed a case mortality of 10·3 per cent.

Measles is most prevalent and most fatal in the winter months of November, December, and January; but it also tends to become somewhat intensified in the late spring (May and June) (fig. 78).

Measles epidemics tend to recur in large towns about every two or three years, with the accumulation of a batch of susceptible children; and since the disease is pre-eminently fatal in the first, second, and third years of life, it follows that if it can be so far discouraged by preventive measures as to acquire epidemicity only every fourth year, a large number of children will have passed the age at which the disease is most fatal, and many lives will be saved.

Measles epidemics, although they recur at such short intervals, do not usually last long. In London and other large cities, measles epidemics tend to run their complete course in from three to six months. In a great city like London, measles epidemics are usually restricted to certain areas, and are not so widely diffused as epidemics of scarlet fever or diphtheria.

Measles and German measles were made compulsorily notifiable in England and Wales in 1915 (The Public Health [Measles and German Measles] Regulations, 1915). The Regulations were rescinded early in 1920, but their enforcement is allowed by the Ministry of Health, on the application of sanitary authorities, in those districts which are prepared to undertake the administrative measures necessary to render notification effective. Upon the receipt of a notification under these Regulations, or on becoming aware in any other way of a case or suspected case of either of these diseases in his district, the Medical Officer of Health, or an officer acting under his instructions, must make such inquiries and take such steps as are necessary or desirable for investigating the source of infection, for preventing the spread of infection, and for removing conditions favourable to infection. If a medical practitioner is not in attendance on the patient, the Medical Officer of Health shall also take such steps as are necessary or desirable for ascertaining the nature of the case.

The local authority may provide or contract for the provision of medical assistance for the poorer inhabitants of the district, when suffering from either of these diseases. In the circular letter of the Local Government Board to County Councils and sanitary authorities, which accompanied the Regulations, it is stated that medical assistance includes nursing assistance, so that sanitary authorities may now make arrangements with nurses or nursing associations for the suitable nursing of measles cases in the homes of the poorer classes. The Local Government Board (now Ministry of Health) are prepared to make a grant to sanitary authorities of one-half the cost of the nursing assistance so provided.

The notification of measles, and the measures resulting therefrom, namely, visiting of cases by health visitors, exclusion of infected children and contacts from school, supply of nurses for the more serious cases, all cause the public to regard the disease with more seriousness, and lead to more general medical attendance upon the sufferers.

The duty of notification was imposed both upon medical practitioners and on parents or guardians or other persons in charge of the patient; but a medical practitioner was not required to notify if a previous case of the same disease had been notified in the same household or institution during the preceding two months.

The Board's Medical Officer has prepared a Memorandum on Measles which sets out the steps which local authorities should ordinarily take under the Regulations. It is admitted that the fact that the disease is infectious before it can be diagnosed makes it difficult to prevent its spread from the first case to other susceptible members of the household, but it is believed that through early notification of recognized cases, the Medical Officer of Health will be able to take action which may often prevent the spread of the disease and secure improved care for sufferers, *thus reducing the proportion of fatal cases and of disabling complications*. One means which will be at his disposal will be the power to give information of cases to school teachers. Each case notified should be regarded as a means of discovering other cases, for it is recognized that cases not seen by a doctor constitute a chief risk of the spread of the infection and of a fatal result in the individual patient. Again, it is recognized that as a large proportion of the fatal cases of measles occur in infancy, removal to hospital is difficult, while the explosive character of epidemics makes it unlikely that the majority of cases can ever be treated in hospitals. It is thought, however, that all sanitary authorities should make some provision for the hospital treatment of a certain number of cases. The average number of deaths occurring annually during recent years in England and Wales from measles is 11,000.

Efficient home isolation of infant sufferers from measles in the dwellings of the poorer classes is generally impracticable; and without the means of offering hospital isolation, the compulsory notification of measles will probably have only a limited effect in reducing the frequency and wide spread of measles epidemics. Home visitations and advice and skilled nursing (with hospital isolation in selected cases) should help to control the complications and after-effects of the disease, and thus reduce the mortality.

If notification is to prove of service, every possible use must be made of the information it provides. Every infected household

must be promptly visited; the source of infection traced; the existence of unnotified cases discovered, if possible, from the clues afforded by the notified cases; schools, libraries, etc., must be communicated with; premises must be inspected; and suitable isolation at home insisted upon (where possible). Now, all this will entail a large staff, which must either be formed during measles epidemics by temporary diversion of Public Health Officers from other duties to measles work, or by engaging the services of more or less qualified women to act as temporary health visitors. There are disadvantages in both courses, and the future can only show if the energies expended in this direction are justified by the results attained.

Occasionally measles is responsible for considerable loss of school attendance. To reduce this to a minimum it is now advocated that a "measles history" of the school children attending each class should be kept; and when a child is suspected to be suffering, and the record shows that he has not had the complaint, and is therefore susceptible, he should be sent home. If, when the disease is rife, the class contains a large proportion of such susceptibles, it should be promptly closed.

Dr. Thomas found: (1) that in London, except in the better class districts, 75 per cent. of the scholars above five years of age are protected by a previous attack, and therefore at present the disease can spread but little in classes of scholars above that age;[1] (2) that a class of over 30 per cent. of susceptibles is one in which the disease tends to spread; and (3) that, if children under five were excluded, school closure for measles would be unnecessary in London. When school closure is resorted to, it must take place before the "first crop" of cases occurs, if any useful purpose is to be effected.

It is highly desirable that measles should be definitely brought within the scope of the expression "infectious diseases," as used in the Public Health Acts of 1875 and 1891 (London), in so far as relates to wilful exposure of sufferers.

Rubella, or "German Measles."—This is a specific infectious fever, propagated by a specific contagium, and not a hybrid between measles and scarlet fever, from neither of which diseases is it protective. The infection is feeble and requires intimate

[1] This is one of the circumstances which point to the desirability of not permitting children to attend school before they have reached five years of age.

communication for its conveyance. It very rarely spreads by fomites or third persons. It has a usual incubation period of fourteen to eighteen days, but this may vary from ten days to three weeks, and the patient is infectious for a few days only. It is not a disease of such common occurrence as measles or scarlet fever, and the illness produced is almost invariably very mild, complications and sequelæ being rare. Children and young adults are most susceptible, and the disease is most prevalent in the spring and early summer. The disease was compulsorily notifiable under the Public Health (Measles and German Measles) Regulations, 1915.

Whooping Cough.

This is a specific infectious disease, the infection being given off in the secretions from the lungs. The specific organism is the *Bacillus pertussis*, discovered in 1906 by Bordet and Gengou. It may be cultivated from the sticky muco-purulent expectoration brought up at the end of the paroxysms of coughing, but disappears from the sputum usually within a month of the onset of illness. The period of infectivity probably corresponds with the presence of the bacillus in the expectoration. The infection is probably not carried far in the air, but may cling to articles of clothing for a time. The period of incubation may last from one to three weeks, and the period of infectiveness is usually not less than four to five weeks from the onset of cough, and may be longer.

Infants and young children are especially susceptible, and comparatively few escape attack. The younger the child, the greater is the likelihood of the attack proving fatal; 40 per cent. of the mortality from whooping cough occurs in the first year, 30 per cent. in the second, 15 per cent. in the third, and 6 per cent. in the fourth. Girls suffer more from severe attacks which end fatally than boys, and their liability to contract the disease is also probably greater. In the first two years of life the proportion of deaths to attacks cannot be less than 10 per cent., and is probably higher. After the third year this proportion is not more than 2 per cent. The case mortality of patients admitted to the Metropolitan Asylums Board Hospitals in 1915 was 11 per cent. Adults seldom suffer, as they are so generally protected by an attack in childhood; but if unprotected they are equally liable with children.

Whooping cough is now the most fatal of all the infectious complaints of childhood under the age of five years; the deaths being due in most cases to pulmonary complications (broncho-pneumonia). For the seven years ending 1921 the average death-rate per 1,000 at all ages was 0·16. Between 1871 and 1880 the death-rate for all ages averaged 0·5 per 1,000.

Whooping cough occurs in regularly recurring epidemics every few years, but it has an exceptional prevalence and fatality in the spring. The seasonal curve attains its maximum late in March or early in April, and from that point rapidly declines (*see* fig. 78).

Outbreaks of whooping cough and measles frequently occur at the same time, and the preventive measures in both diseases are similar.

Varicella.

Varicella, or chicken-pox, is often mistaken for mild or modified attacks of small-pox, but the two diseases are quite distinct. It is a mild disease, but rarely fatal when uncomplicated with other disease, and children are mainly attacked. The incubation period varies from thirteen to nineteen days, and is commonly about fourteen days. The infection of varicella is very considerable from the first, and may possibly remain active for some time in fomites. The patient should be isolated until the last scab has fallen off.

It is now customary to make varicella a compulsorily notifiable disease, when small-pox threatens in a district, owing to the difficulties of diagnosis between the two diseases.

Mumps.

Often in cold and wet weather an epidemic of this disease breaks out, the infection spreading with great rapidity, but giving rise to little, if any, mortality. Outbreaks are sometimes associated with an epidemic of measles. Nothing is known of the etiology of the disease, but it is probably microbic in origin, the organism (which is probably ultra-microscopic) entering the gland from the mouth by way of Stenson's duct. One attack generally confers immunity from others. The disease attacks chiefly the early age-periods of life, and the incubation period is generally three weeks, but may vary from fourteen to twenty-five days. The swellings of the parotid and submaxillary glands,

which are the most prominent symptoms, generally remain for about a fortnight.

Occasionally epidemics occur among young adults; and then serious complications are by no means uncommon, and deafness, etc., may result.

Typhus.

A specific contagious disease, but almost invariably found to be associated with conditions of filth, privation and overcrowding in large towns amongst poor working-class populations. The usual period of incubation is about one to two weeks. The characteristic rash (a macular roseola) comes out on the fifth day, and disappears in from four to eight days. During epidemics mild and abortive forms may be prevalent. The female sex and the age-period of fifteen to thirty years appear to be the most susceptible.

It was formerly believed that the infection of typhus was air-borne by means of exhalations from the skin or droplets from the breath of patients, as it had long been noted that in well-ventilated rooms and houses the disease rarely spread from the original case. It is now, however, fairly well substantiated that lice, especially body-lice, are necessary for the spread of the disease, and that typhus does not spread in the absence of lice. The old observation that typhus spreads in close and stuffy rooms, but not where there is ample ventilation, is accounted for by the fact that typhus chiefly prevails in Europe in winter, when the temperature is cold. The louse is very inactive until the temperature approaches 20° C., and will not change his host when the surrounding air is cold. In close, warm atmospheres lice more readily do so. The fact also that persons who contract typhus may assert that they have been free from lice, and have not noticed any lice upon their bodies or clothing, or felt any bites, may be explained by the fact that the bite of the body-louse produces but little irritation, and leaves only a transient mark, and bites may be inflicted by larval lice which are too small to be easily detected. The experience during the Great War, in the many countries and amongst the diverse armies and populations that were attacked with epidemic typhus, was undoubtedly to the effect that where prophylaxis against lice had been carefully and thoroughly carried out, the spread of the disease was completely checked.

Under war service conditions, body-lice are very general, and the lice act as transmitters of the typhus infection, should the disease be introduced amongst the troops. In practice it is found very difficult, if not impossible, to prevent soldiers becoming verminous on active service, as the crowding of billets and camps and trenches, and the use by clean troops of infected huts, beds, and trenches, is a necessary feature of the soldier's life.

Experiments upon apes show that the virus of typhus fever becomes very much more virulent by its five days' sojourn in the louse; and further passages from human beings to lice exalt the virulence of the infection still further. Bugs and fleas do not transmit the disease.

Typhus may be transmitted to monkeys by inoculating them with the contents of infected lice that have been crushed or with the fæces of infected lice, the lice or their fæces becoming capable of conveying infection from two to eleven days after feeding upon typhus-infected blood. The blood in typhus cases is found infective from the third to the tenth day of attack. It is not yet settled if the ova of infected lice contain the virus.

The causative organism of typhus has not yet been found. In 1916 Rocha Lima called attention to the presence of very minute bodies found in the alimentary canal and its epithelial lining of lice which had fed upon typhus patients. These he named *Rickettsia prowazeki*, after Ricketts and Prowazek, who died of typhus contracted in the course of investigations into the disease pursued independently in different parts of the world. These Rickettsia bodies have, however, never been isolated and grown in pure culture, and they have been found in lice which have fed upon healthy people in whom they produced no disease, as well as in lice fed upon cases of trench fever, Volhynia fever, war nephritis, and other diseases.

Another organism associated with typhus is *Bacillus X* 19, which was isolated from cases of typhus by Weil and Felix in 1916. The remarkable feature of *Bacillus X* 19 is that it presents a high degree of agglutinability in the presence of serum from typhus patients (the Weil-Felix reaction). This reaction has great diagnostic value, as it occurs in from 90 to 100 per cent. of typhus cases, and sometimes in dilutions of the serum as high as 1-30,000, about 50 per cent. of the cases giving the reaction by the fifth day, and practically all by the tenth day of the disease. The bacillus does not appear to have been found in infected lice.

The disease is liable to be mistaken for enteric fever, pneumonia, meningitis, and even scarlet fever and measles. Ill-defined illness often precedes attacks, and these are characterized by their sudden onset and the late appearance of the rash. The symptoms of the disease are often mild and atypical in children.

Being so closely associated with overcrowding, typhus increases in intensity during cold weather, when there is an inducement for many people to huddle together to keep warm. In some of our large towns, epidemics have recurred in certain poverty-stricken quarters with considerable regularity, as fresh susceptible individuals accumulate.

The mortality from typhus has undergone an enormous diminution in this country during the last twenty years. Before 1869, typhus, enteric fever, and simple continued fever were included in the Registrar-General's returns under the generic heading of "Fever"; but since that date mortality returns of these three diseases have been presented separately. In 1869 the death-rate from typhus in England was 0·193 per 1,000 living at all ages; but for some years past the annual rate has been infinitesimal.

Having regard to modern views on the causation of typhus, it is evident that the chief prophylactic measure is the destruction of all lice, nits, and ova on the bodies, clothing, and bedding of infected persons. The room occupied should be sulphur fumigated or sprayed with strong disinfectant. The patient should be removed to an isolation hospital, where he should preferably be treated in an open tent or open-air ward. His chances of recovery are best in the open air, and there is less liability of transference of infection to nurses and attendants in the event of the patient not being entirely disinfested of lice.

Simple Continued Fever.

This is, probably, in a large majority of cases, a convenient term for the registration of deaths from undiagnosed and obscure cases of fever, such as may occur in typhus, general tuberculosis, septicæmia, pneumonia, and intermittent fever. The late Dr Longstaff was of opinion that only a very small proportion of these deaths, if any, are due to enteric fever. Simple continued fever as a cause of death exhibits a decrease in the last twenty years closely analogous to that of typhus (in 1867 the death-rate was 0·24 per 1,000; in the three years ending 1913 the death-rate

was nil). This decrease is, no doubt, due to greater precision in diagnosis. The term " Simple Continued Fever " is no longer used by the Registrar-General, such conditions being grouped under " Deaths from Ill-defined Causes, (D) Pyrexia." In the military and naval services the term used is " Pyrexia of Uncertain Origin " (P.U.O.).

Relapsing Fever.

This disease is of world-wide distribution, and is also known as famine fever, as, like typhus, it is often associated with conditions of famine. The causative organism is a delicate spiral filament known as *Spironema recurrentis*, or an allied organism, *Sp. duttoni*. The relapsing fever of Europe is conveyed by lice, *Pediculus humanus*, and possibly by the common bed-bug, *Cimex lectularius*, as well; whilst the Indian disease is due to lice, and the African disease to ticks, *Ornithodoros moubata*.

The incubation period is usually two to ten days, and the primary fever lasts from five to seven days. Occasionally a rash of rose-coloured spots is noted during the attack, and sometimes petechiæ. An apyrexial period of seven to nine days succeeds the first attack, and then a second attack occurs, usually milder than the first, and not lasting so long. In some cases a second relapse may occur, usually about the twenty-first day from the first onset of symptoms. Prophylaxis is chiefly concerned with the destruction of lice, bed-bugs, or ticks, according to the mode of transmission of the invading spironema.

Trench Fever.

This disease, whilst not very dangerous to life, caused during the Great War high rates of sickness and invaliding amongst armies in the field. The disease is spread by means of body-lice, *Pediculus corporis*, but the virus is not imparted by the bite of the louse, but by the excreta of the louse. About a week after a louse has fed on the blood of a trench-fever patient, its excreta become infective, the infection being introduced into a healthy person by scratching. The organism causing the disease has not yet been identified, but it appears to pass through a part of its life-cycle in the body of the louse. The usual method of spread of the disease is by infestation of healthy persons by infected lice, but clothing worn by infected persons and free

from lice, but contaminated by infected lice excreta, may also aid in the transmission of infection, if the dried excreta have access to sores or scratches on the body-surface.

Diphtheria.

The etiology of this disease is still to a certain extent veiled in obscurity. Whilst on the one hand it cannot be doubted that the contagion is transmitted from the sick to the healthy, on the other hand diphtheria outbreaks in rural districts at times appear to originate independently of the infection of a pre-existing case. But probably the diphtheria contagion has the power, under certain conditions, of lying latent for long periods of time in the nose and throat of convalescents and contacts (carriers), with the capacity of renewing its virulence under special circumstances; and, as in the case of enteric fever, mild and unrecognized forms of the disease and "chronic carriers" may account for much obscurity of origin.

Occasionally outbreaks have been traced to children with ear discharges, *B. diphtheriæ* being present in the discharge in almost pure culture.

In some instances of such occurrences the explanation may be that the organism of diphtheria, the Klebs-Loeffler bacillus, is sometimes present in a non-virulent or slightly virulent form in the mouths of healthy persons; and if a slight sore throat or tonsillitis occurs in such a person, then the bacilli may become virulent, and give rise to true diphtheria.

A bacillus, known as the pseudo-diphtheria bacillus (Hoffmann), has been described by many observers in the throats of apparently healthy children, as well as in those of patients convalescent from diphtheria. This pseudo-diphtheria bacillus is morphologically and culturally allied to the Klebs-Loeffler bacillus, but is usually non-pathogenic to animals. The relation between the two organisms has not yet been conclusively shown. Most authorities agree that Hoffmann's bacillus does not necessitate the preventive measures undertaken for coping against dihptheria.

The diphtheritic contagion is given off from the body in the secretions from the mouth, nose, and throat; and, although probably not far diffusible in the air, may cling for a time to infected articles of clothing and bedding.

As is the case with some other infectious maladies, there appears to be in certain individuals a peculiar hereditary or family susceptibility to attacks of diphtheria.

Season has a marked influence on the manifestation, and, above all, on the mortality from diphtheria. Increased prevalences of the disease commonly commence in September, reach their highest point during October and November, and then subside slowly during the following months—the smallest amount of mortality being witnessed from May to July. There is some excess of diphtheria mortality in females as compared with males. It is probably due, at all periods of life, to greater exposure of females to infection in nursing (Thorne Thorne). The incubation period is usually under four days' duration, rarely, if ever, less than two or more than seven days.

Diphtheria occurs endemically in certain localities, localized epidemic extensions taking place from time to time. It has been a matter of observation that certain districts, in which the surface soil is cold and humid, and where damp houses and privy and drainage nuisances abound, or where the aspect involves much exposure to cold and wet winds, suffer from an exceptional incidence. The broad geological features of a district—the permeability or otherwise of the surface strata—have not, as such, any observed influence on the development and diffusion of the disease; but such topographical relations as facilitate the retention of moisture and organic refuse in the surface soil, or involve bleakness of site or exposure to cold and wet winds, appear to be of importance.

According to Newsholme, diphtheria tends to become widely epidemic in years of deficient rainfall, the epidemic wave becoming most marked when three or more years of deficient rainfall follow each other.

Until lately diphtheria was regarded as being to a far greater extent a rural than an urban disease, but during the last thirty years diphtheria mortality has progressively increased very greatly in London and some other large cities. The average death-rate of the ten years 1871-80 was 0·12 per 1,000. The average of the decennium 1881-90, however, was 0·16 per 1,000; and of the decennium 1891-1900 0·26 per 1,000. Since 1899 there has, in London, been a steady decline in diphtheria mortality. The same progressive increase and subsequent decrease has been witnessed in some of the other large

cities and towns. In England and Wales in 1921 the death-rate from diphtheria per 1,000 living at all ages was 0·12.

The incidence of the disease is most marked in children between the ages of two and twelve years, and subsequently decreases with every year of advancing age. As a rule, the younger the child, the greater the chance of an attack proving fatal. The average mortality of cases notified in London (average of 1890-94) was 23·8 per cent., and is now about 7·5 per cent., antitoxin having been in regular use since the end of the year 1894. The case mortality in the Metropolitan Asylums Board Hospitals was, in the pre-antitoxin days, 30·3 per cent. (average of 1888-94), and is now under 9 per cent., the case mortality among those treated with antitoxin on the first day of the disease being only about 3 per cent.

School attendance is now acknowledged to be a very potent factor in the spread of diphtheria, as in scarlet fever and measles. Infection is spread by the attendance at school of mild or unrecognized cases, and this is especially likely to occur in the public elementary schools, where the class-rooms are often overcrowded and badly ventilated, and the children are brought into very close contact at the most susceptible age-periods. Sir Shirley Murphy has shown that in London the increased incidence of diphtheria among children from three to ten years of age (school age) first became conspicuous in the year 1871—the year, that is, in which the Elementary Education Act first became operative; that there is a marked decline in incidence during the holidays, and a subsequent rise with the reopening of the schools (due allowance being made for the incubation period and for some delay in notification). Although during the summer holidays there is also a decline in incidence among persons over ten years of age, it is never so great as the decline among children of the school age (three to fourteen).

Prevalences of recognized diphtheria are very commonly associated in their beginnings, during their continuance, and after their apparent cessation, with a large amount of ill-defined throat illness. Vincent's angina is a disease allied to diphtheria, which spreads from direct or indirect contact. While the patient's symptoms in some cases simulate those of diphtheria, they more commonly take the form of deep ulcerations on the tonsils, palate, etc. The disease is most frequent amongst children from eight to ten years of age.

Diphtheria epidemics are occasionally inextricably mixed up with outbreaks of scarlet fever and measles. There is no reason to believe that diphtheria is in any way interchangeable with scarlet fever or measles, in the sense that the infection of the one disease may produce the other; but it would seem that the morbid condition of the throat left after scarlet fever or measles predisposes the sufferer to become receptive of the diphtheria contagion which may at the same time be present.

Patients convalescing from scarlet fever are not infrequently attacked with diphtheria ("post-scarlatinal diphtheria"), the infection of which is probably introduced into the scarlet fever wards by an unrecognized case of diphtheria. The prevention of post-scarlatinal diphtheria is a matter of great difficulty. A bacteriological examination of the throats of all cases on admission would prevent the introduction into the fever wards of cases of diphtheria running concurrently with scarlet fever, but would not necessarily lead to the isolation of patients in the incubation stage of diphtheria.

The virus of diphtheria attenuated as to its virulence by exposure to atmospheric conditions is, no doubt, at times widely distributed among populous communities. The attenuated bacilli very readily regain their virulence when they become implanted on human fauces weakened by the attacks of other organisms, especially streptococci, occasionally present in drain and sewer emanations (drain throat), and the organisms associated with measles, scarlet fever, and rötheln.

Faulty sanitary surroundings (drainage and filth nuisances) tend to the production of diphtheria in the same way, namely, by engendering a morbid condition of the tonsils favourable to the growth of the diphtheria contagion if implanted thereon.

An affection of the throat, in many respects similar to human diphtheria, has been noticed as occurring in pigeons, fowls, and other birds, during periods of epidemic prevalence of this disease. According to Klein, a very similar disease can be produced in cats by subcutaneous inoculation of cultures of the *Bacillus diphtheriæ*, giving rise at first to a tumour at the seat of inoculation, subsequently followed by broncho-pneumonia and kidney degeneration. But the bacillus is only recoverable from the tumour, and is not found in the blood or affected organs, pointing to the visceral disease being a result, as in man, of the action of a chemical poison—an albumose (toxin)—produced by the bacillus

at the seat of inoculation and absorbed from thence into the system. The disease called diphtheria in pigeons, calves, and other animals is due to a different organism, and appears not to be communicable to man; but Cobbett has recorded a case of natural diphtheria in a pony, from which a child contracted the disease; and the diphtheria bacillus has been isolated by Dr. Tew from the apparently healthy throat of a cat.

There is abundant evidence to show that diphtheria has often been conveyed through the medium of milk, and this infectivity of the milk has been ascribed on some occasions to some morbid condition of the cow or cows. Klein has shown that cows and calves, when subcutaneously inoculated with cultures of the *Bacillus diphtheriæ*, develop a disease similar to that observed in cats, and usually proving fatal in the course of two or three weeks, the chief post-mortem signs being intense broncho-pneumonia and necrotic patches in the liver.

There is little or no evidence pointing to the spread of the disease by drinking contaminated water. Klein has stated that the *Bacillus diphtheriæ* is killed when kept for a few days in pure water, on account of its not finding sufficient nutriment.

The specific bacillus may persist in the mouth for a considerable time after the false membrane has disappeared. Dr. Hermann Biggs (New York Health Department) has subjected 405 cases of true diphtheria to repeated bacteriological examinations during the course of the disease, and during convalescence. In 245 cases (60·5 per cent.) the Klebs-Loeffler bacillus disappeared within three days of the complete separation of the false membrane; in 103 cases (25·4 per cent.) the bacilli persisted for seven days; in 34 cases (8·4 per cent.) for twelve days; in 16 cases (4 per cent.) for fifteen days; in 4 cases (1 per cent.) for three weeks; and in 3 cases (0·75 per cent.) for five weeks, after the time when the exudation had completely disappeared from the upper air-passages.[1] In many of these cases the patients were

[1] Sternberg in the 1901 edition of his book quotes the following: "Park and Beebe (1894), in an extended research made for the purpose of determining the persistence of the diphtheria bacillus in the throats of convalescents (2,566 cultures made), found that, in 304 out of 605 consecutive cases, the bacillus disappeared within three days after the disappearance of the exudate (that is, in 50·25 per cent.); in 176 cases (29·1 per cent.) it persisted for seven days; in 64 cases (10·6 per cent.) for twelve days; in 36 cases (5·9 per cent.) for fifteen days; in 12 cases (2 per cent.) for three weeks; in 4 cases (0·66 per cent.) for four weeks; and in 2 cases (0·33 per cent.) for nine weeks."

apparently well many days before the infectious agent had disappeared from the throat. Such results as the above are suggestive of a method of dissemination of the disease by the mixing of convalescents with healthy people, whilst their throat secretions still contain specific bacilli. It is never safe to allow recovered patients to mix with healthy people until at least fourteen days have elapsed since the disappearance of all membrane. During the whole of this time the mouth and throat should be repeatedly washed with disinfectant lotions; and as the bacilli are frequently present in the nasal discharges, an antiseptic nasal douche should also be used, especially if much discharge from the nasal cavities was present during the acute stage of the disease.

As regards the presence of carriers in the general population, it has been estimated that even in non-epidemic periods about 1 per cent. of the population may be carrying diphtheria bacilli in their throats, and during outbreaks this number may be much exceeded. In a majority of these carriers the bacilli are non-virulent to guinea-pigs, but the percentage of carriers having virulent bacilli seems to vary considerably according to circumstances. Most of these examinations have been made in respect of collections of children in schools or institutions where diphtheria outbreaks have occurred; and as the numbers examined have not usually been large, too much reliance should not be placed on the recorded results, as indicating the percentage of virulent to non-virulent carriers in larger populations.

Of those contact carriers of the germ who never suffer from constitutional symptoms, and who may form as many as 25 per cent. of the children of infected school class-rooms, it appears that whereas some harbour the germ in a virulent form, in others the germ is non-virulent. There have been many recorded instances where it is believed that the discovery of apparently healthy carriers, and their exclusion from school, has succeeded where all other measures have failed in eradicating the disease. In some epidemics many partially virulent strains of diphtheria have been isolated from carriers, and there is a possibility that non-virulent bacilli in an individual may from some unknown cause acquire virulence; and so it looks as if even a test of virulence by animal inoculation would be of only partial value from the administrative standpoint.

In their cultural and staining reactions virulent and non-

virulent diphtheria bacilli are exactly alike. They can be distinguished only by injection into the guinea-pig, a positive result being reported if the guinea-pig dies with characteristic lesions within four days of inoculation. The diphtheria bacilli in a majority of healthy carriers (not convalescents or contacts) are non-virulent, and as the possibility of such bacilli becoming virulent in the throats of healthy persons is a remote one, it is not generally considered necessary to isolate healthy carriers. In any case of suspicion, however, the bacilli should be tested for virulence.

There is evidence that in this disease an intimate personal association and contact, as in playing, working, or sleeping, is generally necessary for the transference of the bacillus from one person to another. Probably this circumstance and the attenuation or loss of virulence suffered by the organism during its sojourn in the throat of an immune person best explain the fact that, as Sörensen has found, while bacilli were present in 10 per cent. of cases discharged from a hospital, only 1·1 per cent. of such cases gave rise to "return cases."

A systematic search through a widening circle for mild unrecognized cases and carrier cases is essential to a successful campaign against the spread of diphtheria.

It is probable that the Klebs-Loeffler bacillus may be much more widely distributed in the throat secretions of children than at one time was considered possible. In large towns, when diphtheria is endemic, it would appear from recent statistics that from 5 to 10 per cent. of the children of the working classes have the bacillus in their throats; and in the majority of these cases there is no evidence of any unhealthy condition of the fauces. These "carrier cases" are of importance when an outbreak of diphtheria occurs in a school. The examination of the throats of all the children, and of the nasal and ear discharges of those with "running noses" or ears, may reveal in some the presence of the specific bacillus. The isolation of the children with nasal or ear discharges often proves effective in limiting the spread of the disease.

During the prevalence of the disease at schools a prompt bacteriological examination of suspects often prevents a needless loss of school attendance. In the London County Council's Schools it has been found safe to ignore the presence of the pseudo-diphtheria bacillus among scholars; but, when this

organism is found during the prevalence of diphtheria in virulent form, it is wise to isolate those scholars who are harbouring it.

Outside the body the action of light and air and alternating moisture and dryness destroys the virus with considerable rapidity. The bacilli can resist a dry heat of 98° C. for one hour, but a moist temperature of 58° C., acting for ten minutes, is sufficient to kill them, so that boiling water or disinfection in a steam chamber is always efficacious in destroying their vitality.

Klein has shown experimentally that the virulence of *B. diphtheriæ* can be increased by placing it under symbiotic conditions with *Streptococcus pyogenes*; that is to say, it may be inferred from his experiments that a mixed infection of these organisms is liable to produce an especially virulent type of diphtheria.

An antitoxin serum has been introduced through the observations of Behring, Kitasato, and others, which not only has the power of conferring immunity upon animals, but also of arresting the disease after it has commenced in the human subject. The serum is obtained as follows:—The virulent Klebs-Loeffler bacillus is grown in broth for seven to twelve days at 35° C., when a maximum quantity of toxin will be furnished in the liquid by the metabolism of the bacilli. The culture liquid is then filtered through a porcelain filter, to arrest all microbes, and the clear liquid resulting is injected subcutaneously into a horse. Gradually, by repeated injections of this toxin over a period of two or three months, the horse is brought into a condition in which its serum possesses very high antitoxic properties. The animal is then bled, and the serum obtained from the drawn blood is mixed with a little weak antiseptic, usually 0·2 per cent. carbolic acid, filtered through a porcelain filter, and after standardization is stored ready for use (*see* p. 425).

That the lessened case mortality from diphtheria which has resulted from the use of antitoxin is not attributable to any natural attenuation of the virus, or to a change in the conditions of environment, is proved from the fact that in parts of Germany and elsewhere on the Continent, whilst the local incidence of the disease has remained unchanged among people in the same community and influenced by similar sanitary environments, there is a reduction in the case mortality only among those who have been treated with antitoxin.

In order to facilitate an early application of the remedy, some local authorities keep a stock of antitoxin at their public

offices, and supply it to practitioners at cost price, or gratuitously in the case of poor patients.[1] The provision is a useful one, for experience has shown the high importance of an early application of a large initial dose, ranging from 6,000 to 8,000 units, according to the gravity of the symptoms.

Diphtheria antitoxin also possesses valuable prophylactic properties, and may be used with advantage in doses of at least 500 to 1,000 units for the protection of children who are or have been exposed to the risks of infection. Regard, however, must be had to the possible production of anaphylaxis on the injection of a second dose (*see* pp. 427 and 428).

There can be no question that many people possess a natural immunity to diphtheria. Schick devised a test by which the susceptible can be distinguished from the non-susceptible. Those who are found to have no natural immunity can be given an artificial immunity. The test is performed by injecting intradermally—not subcutaneously—a carefully standardized and diluted diphtheria toxin (one-fiftieth the minimum lethal dose for a guinea-pig). If there is no immunity, there is a skin reaction of more or less severity. To confer artificial immunity, 1 c.c. of a carefully standardized toxin-antitoxin mixture is injected subcutaneously, a second injection being given after a week's interval. The immunity so conferred begins to develop in from two to twelve weeks after the second injection, and persists for three years, possibly for longer.

The reaction of the skin in the Schick test may be due not to the susceptibility of the individual to diphtheria toxin, but to his susceptibility to the autolyzed proteins present in the toxin and due to its preparation. The diphtheria toxin is destroyed by submission to a temperature of 75° C. for ten minutes, but not the autolyzed proteins, so in practice two injections should be made, one on the right arm of toxin unmodified by heat, and one on the left arm of toxin modified by heat.

Enteric Fever.

Typhoid or enteric fever is a specific disease dependent for its propagation upon a specific virus—the *Bacillus typhosus*. It is not always possible to establish the dependence of an outbreak on a pre-existing case; but it is not necessary for this reason

[1] The Local Government Board advise this course, and sanction the necessary expenditure.

to assume that the disease can originate independently—from organic filth apart from the infection of a previous case—seeing that the contagion may possibly survive in polluted soil for a certain period. Besides this, enteric fever is sometimes a mild disease and unrecognized even by the patient himself, who goes about his ordinary avocations unaware that he may be spreading contagion broadcast; and the proof now forthcoming as to the existence of " chronic carriers " is of especial importance in this connection.

The period of incubation is usually a long one, from ten to fourteen days. The limits of its maximum duration are not accurately known, but in rare cases it may be prolonged to twenty-one days, or even to twenty-three.

Post-mortem the *B. typhosus* is found in the gall-bladder, either in the bile, in the walls of the gall-bladder, or in both situations. The bacillus can be isolated from the blood up to the tenth day of the disease, that is to say, previous to the formation of agglutinins in the blood in appreciable quantity. In severe cases and in relapses, where agglutinins undergo a temporary decrease, the *B. typhosus* may again be found in the blood.

The bacilli have been shown by Conradi to be present in the blood during the incubation period, and even before the bacilli can be found the presence of antibodies may be demonstrated by the precipitin test, as was shown by Fornet. With the aid of the Drigalski-Conradi medium and the agglutination test, strong evidence of the presence of *B. typhosus* in the blood may be obtained in the course of twenty-four hours, and within forty-eight hours this evidence may be confirmed sufficiently to warrant the undertaking of special preventive measures. It is obvious that methods of this kind must be more generally adopted if we are to obtain full information with regard to the incubating and mild or abortive cases which contribute such a large proportion to extensive epidemics.

When the bacillus disappears from the blood, it is deposited in the adenoid structures—the spleen, Peyer's patches in the intestines, and the mesenteric glands. Frequently the bacillus can be isolated from the fæces during the incubation period, and in the early days of illness, with difficulty during the height of an attack, but in a large number of cases during convalescence. The bacillus is not usually found in the urine until the end of the second week of illness (30 per cent. of cases), but it is then

found well on into convalescence. Drigalski has recovered the bacillus from the tongue and tonsils of sufferers.

Infection is transmissible : (*a*) by those who are actually suffering from a recognizable attack, typhoid bacilli being especially numerous in the stools during the third and fourth weeks of the illness; (*b*) by those who are suffering from an "ambulatory" type of the disease—the type that is mild, obscure, or unrecognizable clinically; (*c*) by those who are "contacts"—*i.e.*, those who have been infected, and who for a time pass *B. typhosus* in their excreta, but are apparently not in any way affected in health thereby; (*d*) by those who are convalescent from the disease, but whose urine contains the specific bacilli, often in pure culture; and (*e*) by those probably very exceptional cases (about 3 per cent. of the total) known as "chronic carrier" cases, in which an attack of enteric fever (mostly in women, about 75 per cent. of these cases being females) is succeeded by an indefinite period of latent infectivity lasting sometimes for many years, and due apparently to the discharge from time to time of virulent typhoid bacilli in the fæces or urine, or both, for certain periods, such periods alternating with others when the discharges are free from infective organisms. The habitat of the typhoid bacilli in the body in many of these cases appears to be the gall-bladder; and Dr. Davies, the M.O.H. of Bristol, has noted that in the cases investigated by him the months of May and June were those in which the bowel discharges of the "chronic carrier" resumed infectivity. Carrier cases who are engaged in the constant handling of food (such as cooks and dairy employés) have in several recorded instances been responsible for an outbreak of enteric fever.

Special mention deserves to be made of the now famous Strassburg case, described by Kayser in 1906. It was observed that almost every new employé in a bakery, kept by a woman who had suffered from typhoid fever ten years previously, became seriously ill, with intestinal symptoms resembling those of typhoid fever. At length the fæces of the woman were examined, and were found to contain the specific bacilli in large numbers.

It has been estimated that in the United States, where enteric fever is more prevalent than in this country, from 1 in 500 to 1 in 250 of the general population are chronic carriers of enteric fever bacilli.

It is important to realize that in enteric fever the urine in the

later stages of the illness and in convalescence may be more potent for mischief than the fæces, as in a certain proportion of cases of this disease, which, according to the recorded observations, may amount to some 20 or 30 per cent. of the total, the urine contains enormous numbers of *B. typhosus*.

Inasmuch as the soiling of body- and bed-linen and of water-closet seats and chamber utensils is much more readily effected by the urine than by the fæces, it is easy to understand how the hands of healthy persons may become infected by the handling of such objects; and, in consequence, how easy would be the transmission of infection in this manner, whilst the source of the mischief would in many instances be quite unrecognized.

Female chronic carriers are about four times as numerous as male, and females also suffer from gall-stones about four times as much as men in the later years of life. *B. typhosus* has the power to precipitate cholesterin from the bile, and so produce gall-stones, and the bacilli have been found in the interior of gall-stones. It seems probable that chronic carriers are due to focal deposits of *B. typhosus* in the walls of the gall-bladder, or in the pelvis and tubules of the kidneys. These focal deposits are probably determined by pre-existing lesions at these sites, which are more common in middle life than in youth, and more common (gall-bladder) in women than in men, thus accounting for the fact that the female sex and middle life exhibit a preponderance of chronic carriers.

Intermittent periods (without any discharge of *B. typhosus*) are much less frequently found in the case of urinary carriers than in the case of fæcal carriers. Chronic fæcal carriers may excrete large numbers of *B. typhosus*, and yet the blood may give a practically negative Widal reaction. Urinary carriers, as a rule, give positive reactions to the Widal test, and always in higher dilutions than fæcal carriers.

Sour milk treatment (lactic acid bacilli, or *B. Bulgaricus*), urotropin and salol, for the disinfection of the urine and the fæces, and the application of the Röntgen rays, have all been tried to cure the chronic carrier condition, but without any considerable measure of success. Autogenous anti-typhoid vaccines are of some value in certain cases which have not passed into the very chronic stage; but in the chronic cases, with definite infective foci shut off from the general circulation by reason of inflammatory processes, the result of local irritation (gall-stones, gravel,

and small abscesses in pelvis of kidney), no measures at present known seem to be of much utility.

According to Forster and Kayser, the serum of those who merely harbour the *B. typhosus* as a saprophyte in the intestine, without having actually suffered from typhoid (" acute carriers "), has generally no agglutinative power. To add to our difficulties in the campaign against this disease, we are unable, in the present state of our knowledge, to free from bacilli those carriers who have been detected, and measures suggested to minimize the risks of infection—*e.g.*, thorough cleaning and disinfection of hands after defæcation and urination, and continuous disinfection of dejecta—are not likely to be carried out by most " carriers," who are under no sort of control.

B. typhosus outside the human body may remain alive for long periods in pure cultures, or in urine or fæces, which contain no other organisms. The presence, however, of *B. coli*, *streptococci*, and other organisms is markedly antagonistic to the life of *B. typhosus*. The larger the proportional numbers of such organisms, the more quickly does *B. typhosus* disappear. Inasmuch as the multiplication of *B. coli*, etc., depends largely on temperature (37·5° C. being the optimum for *B. coli*), the higher the air temperature, the sooner *B. typhosus* disappears. Thus, in England it has been ascertained that the fæces and urine of typhoid carriers may contain *B. typhosus* up to twenty-two days from passing out of the body, whilst in India about five days appears to be the limit. The fingers of a urinary carrier were found one hour after passing urine to be infective, but the fingers of a fæcal carrier gave negative results. Ordinary washing with soap and water and drying the hands with a clean towel removes all trace of *B. typhosus* from the infected hands.

B. typhosus grows freely in sterilized milk, and may persist in it for an indefinite period, but in unboiled milk the *B. coli*, which are always present, outgrow it, and *B. typhosus* disappears within three days. *B. typhosus* will multiply for twenty-four hours in soup, but dies out in two or three days if the soup has not been sterilized. In military uniforms it may survive for three weeks, and for longer in linen articles. It has survived three months in soiled blankets, several weeks in water, and at least for four days in refuse matter and soil. In deep well waters *B. typhosus* survives longer than in surface waters, owing to the smaller number of antagonistic organisms.

Many people who are exposed to the infection of both enteric fever and cholera escape, owing to the virus being destroyed after being swallowed by the acid of the gastric juice. But those who are out of health, or who are suffering from diarrhœa, may offer much less resistance to the invasion of the contagion.

Klein has shown by experiments on animals that the virulence of *B. typhosus*, and to a less extent of the *Vibrio choleræ*, may be enhanced by association (symbiosis) with certain strains of *B. coli*, with the *B.* of Gaertner, and with *B. enteritidis sporogenes* and *B. carnis*, all these organisms being capable of setting up gastro-enteritis, when they happen to be ingested with the specific typhoid or cholera organisms.

Of those who drank the infected water in the outbreaks at Maidstone and Worthing, about 6 per cent. were attacked with the disease. But this figure is obtained from the notification returns, and doubtless many cases of mild infection are never notified; so that the incidence of infection in these outbreaks probably exceeded 10 per cent.

Apparent insusceptibility may sometimes be explained by the possibility that the disease may have been contracted in childhood, when it is often mild and unrecognizable, for, as a rule, one attack confers immunity for the remainder of life. No age and neither sex is free from risk of attack, but those from fifteen to twenty-five years of age appear to be specially prone to suffer. Between the ages of three and twenty years the mortality of females from enteric fever is greater than that of males. The higher death-rate at these ages is due, not to greater liability on their part to contract the disease, but to a higher case mortality, *i.e.*, a larger proportion of attacks proving fatal.

During the period 1871-80 the mortality from enteric fever in England and Wales was at the rate of 0·33 per 1,000 living at all ages; but the death-rate from this disease has undergone for a long period, and is still undergoing, a steady diminution year by year. In 1869 (the first year in which enteric fever returns, as separate from "fever," are obtainable) the death-rate was 0·39 per 1,000, whilst in 1921 the death-rate was only 0·02 per 1,000, a twentyfold reduction. This result may be mainly attributed to the improvements in water supply, sewerage, and domestic sanitary arrangements, throughout the country generally, that have been so marked a feature in the social progress of the last forty years.

The proportion of deaths to attacks in enteric fever cannot be accurately stated, owing to the number of mild cases that escape recognition. In typical cases the mortality varies from 15 to 20 per cent. of the attacks. The average mortality of cases notified in London is about 18 per cent. In early life the type of the disease is less severe than in adolescence and adult age.

Enteric fever is most prevalent, and causes the largest number of deaths, in the late autumn. The seasonal mortality curve (*see* fig. 78) is seen to rise in August, and attain its maximum late in October or early in November, from which point, with the exception of a slight rise in February, it gradually falls.

It is now established that the infection of enteric fever may be conveyed in shell-fish, more especially in oysters, mussels, and cockles, which are collected from tidal waters where the water is liable to considerable pollution from sewage; and it has been shown that the specific bacilli of enteric fever and of cholera are capable of existing in oysters and cockles for some days, and in sea water for several weeks. Nash has shown that boiled cockles taken from polluted layings have given rise to cases of enteric fever, the heat employed in the so-called "boiling" being only sufficient to kill the cockles and open the shells, the internal temperature of the cockles being below the thermal death-point of *B. typhosus*. Klein has shown that when infected oysters are kept in clean, frequently changed, sea water, they rapidly clear themselves of the bacilli. Legislative measures are therefore required in the interest of public health to prohibit the laying down of oysters in dangerous localities; and to that end all oyster layings, fattening beds, and storage ponds should be made registrable after approval by the sanitary authority, and also subject to frequent inspection. Section 4 of the Infectious Diseases (Prevention) Act, 1890, which enables authorities to prohibit the supply of milk which is causing, or is likely to cause, disease, might also, with modifications, be made to apply to oysters and other shell-fish. The public should, moreover, be guarded against the importation of infected oysters from abroad (*see* Chap. XIV.).

The presence of typical *B. coli communis* in considerable numbers in the body of the shell-fish is usually regarded as sufficient evidence of fæcal contamination, as in shell-fish derived from waters free from pollution these organisms are not found.

There is some evidence that the consumption of fried fish has been productive of enteric fever (Dr. Hamer's Annual Reports on the County of London). Such fish are believed to have been brought from polluted areas in the sea in the neighbourhood of sewage-contaminated coasts or tidal estuaries. The process of frying may not always raise the internal temperature of the fish sufficiently high to destroy enteric bacilli; and small fish like dabs and flounders are not always gutted prior to cooking, the gut contents not being properly sterilized.

It is noteworthy that in enteric fever and in cholera, especially when due to polluted water, an outbreak is often preceded for several weeks by cases of "diarrhœa," which may be instances of the mild or "ambulatory" type of the disease. For instance, in the Spanish-American War of 1898 it was found that, in the volunteer camps, 15·3 per cent. of the soldiers who had had no previous diarrhœa developed enteric fever, whereas only 6·8 per cent. of those who had so suffered developed the disease.

Dr. Childs, from a study of the chief outbreaks in this country, concludes that, where the public water supply is infected, the explosive outburst of the epidemic is not indicated by notifications until two or three weeks after the actual infection comes into operation; that the abnormal number of cases of antecedent diarrhœa is a suggestive premonitory sign of an outbreak of enteric fever, and should be bacteriologically examined; and that a large proportion of those who are infected are never notified.

The numerous outbreaks (Caterham, Middlesbro', Tees Valley, Worthing and Maidstone) in which the disease has been shown to be conveyed through the medium of drinking water, point to the necessity of exercising a constant supervision and sanitary control over all sources of drinking water, both by the establishment of protected areas upon the sites from which water is collected for drinking purposes, and also by systematically ascertaining the degree of purity of the water by means of repeated chemical and biological examinations.

Pettenkofer has shown that in Munich, before the town was sewered, and when the water supply was derived from shallow wells, there was a remarkable correspondence between the rise of the subsoil water and the decline in the prevalence of enteric fever, and vice versa. He does not profess to explain this relationship, but demonstrates that the movements of the ground

water were an invariable index to the extent of enteric fever incidence in Munich.

Where flies abound, it is probable that enteric fever is very frequently transmitted through their agency, the flies directly conveying the contagion on their hairy legs from infected excreta to some article of food. Considerable evidence of fly-borne enteric has accumulated from the experience of recent military campaigns, and infected dust is also believed to be an agent in the transmission of the disease.

Maggots bred in the fæces of enteric cases do not produce infected flies, as was at one time suggested. The *B. typhosus* has not been definitely isolated from the intestines of flies so bred. It is even doubtful if the *B. typhosus* is ever excreted in the fæces of flies which have fed on enteric stools, the *B. coli* in the flies' intestines being strongly antagonistic to the typhoid organism. It is possible, however, that the vomit from the crops of flies which have ingested *B. typhosus* may contain the organism. This vomit, or regurgitation from the crop, is a common act when a fly is feeding, and is useful in softening hard material which the fly is endeavouring to absorb. It is possible, therefore, that flies convey infection by organisms carried on their feet, and by regurgitations from their crops, on to the materials on which they are feeding. At any rate, laboratory experiments point to such methods of infection; but, so far, it does not appear that any flies have been captured in a state of nature which have been found definitely infected with undoubted *B. typhosus*.

It is the experience of numerous localities that enteric fever may be endemic notwithstanding a water supply of undoubted purity. In these localities—generally poor and crowded—there are sanitary circumstances which generally conduce to soil pollution, such as defective house and yard drainage and sewerage, unpaved or badly paved yards around houses, allowing refuse to pollute the soil, and, above all, defective privy middens containing considerable accumulations of excreta, much of the liquid part of which finds its way into the soil. Many observers have ascertained that the incidence of the disease is always heavier on houses with dry closets than on those with water-closets; and, among the former, those with middens are more frequently infected than those with pails, the difference being more marked the poorer the class of houses (Boobyer). Sir Arthur Newsholme has pointed out that Nottingham and Leicester possessed two

features in common, some years ago: a conservancy system of excrement disposal, and a high death-rate from enteric fever. Whereas Nottingham has made but slow progress in the adoption of the water-carriage system, in Leicester the progress has been rapid; and as regards enteric fever the death-rate in Nottingham is still high, while that in Leicester has undergone a very marked diminution. Flies and dust may have some share in the propagation of infection from privies and middens to neighbouring dwellings; whilst uncleanly habits, with their tendency to produce contact-infection, are favoured by the retention of excretal matters in the vicinity of houses.

That the disease is frequently communicated by personal intercourse is repeatedly demonstrated by its spread to those in attendance on a patient in dwelling-houses, and even in hospitals.

Goodall has shown from the experience of twelve of the large Metropolitan Fever Hospitals during eight years, that for every 1,000 cases of enteric fever admitted as many as sixteen of the staff contracted the disease.

The serum diagnosis of enteric fever (Widal) is an important means of aiding the clinical diagnosis of the disease; and since it is in the public interest that the diagnosis should be prompt and certain in the case of a disease which so often has a masked and insidious onset, many sanitary authorities now provide medical practitioners with a so-called "diagnosis outfit," containing a small capillary tube for collecting and sealing up some of the blood of a suspected patient. The blood is returned to the local offices, where arrangements are made for testing it at the public expense. The diagnosis outfit also comprises a sterilized swab in a tube for collecting suspected exudation or membrane from the throats of patients thought to be suffering from diphtheria. Similar provisions have also been made in some districts for enabling medical practitioners to avail themselves of the bacteriological diagnosis of tuberculous sputum. Such diagnoses add definiteness to administrative procedure, *qua* isolation, disinfection, and the admission of patients to hospital wards.

The evidence so far recorded of Widal's test establishes the fact that the reaction of the blood on the *B. typhosus*, causing a characteristic clumping of the latter, and a total arrest of motion within a definite time limit, may be delayed, or occasion-

ally may not be obtained, in cases of genuine typhoid infection; and also that it may in some instances occur in non-typhoid cases, though not in an intense degree, nor if high dilution of the serum be used. The average of successful diagnoses approximates, however, to 90 per cent.

In carrying out this method of diagnosis, all that is necessary is to draw a small quantity of blood from the finger or ear of the patient into a capillary tube. The serum reaction is performed by diluting the serum 25, 50, or 100 times with a typhoid broth or emulsion, and then making "hanging-drop" preparations of the different dilutions, which are examined under the microscope for signs of clumping and loss of motility in the bacilli. A time limit of half to two hours, according as the dilution is a low or high one, is given by most bacteriologists.

The value of anti-typhoid inoculations has now obtained general recognition. The material generally used for anti-typhoid inoculation is a suspension of the dead bacilli obtained from a culture killed by heat.

Forty-eight-hour-old bouillon cultures of a laboratory strain of *B. typhosus* are used, and are killed by heating for an hour at 53° C. Lysol is added as an antiseptic in the proportion of 0·4 per cent. of the whole volume of the vaccine (Leishman). Usually two inoculations are given, with an interval of ten days, the dose of the first inoculation being 500 millions of bacilli, and of the second, 1,000 millions. Generally some degree of malaise is caused; and in a small percentage of cases there is a tendency to syncope; occasionally a rigor occurs; and there is always a slight pyrexia which subsides after about twenty-four hours. The results of anti-typhoid inoculation in the British Army have been extremely good, the number of cases of enteric fever occurring among non-inoculated soldiers serving abroad being more than five times as great as amongst the inoculated. The severity of attack is markedly less in the inoculated men, and there are a smaller proportion of complications and relapses. When troops are going to places like India, where paratyphoid fevers are not uncommon, the practice is to make the vaccines polyvalent for these diseases as well as for enteric fever (T.A.B.V. or typhoid and paratyphoid A and B). The first inoculation usually contains 375 million paratyphoid A and the same number of paratyphoid B organisms, the second inoculation containing double these numbers. The extraordinarily successful results attending

anti-typhoid inoculations of the troops who have served at the various seats of war are now well established.

The experience of the whole period of the Great War as regards the results obtained by typhoid and paratyphoid vaccines cannot be told until the medical history of the war is completed, but the results for the two years 1916 and 1917 are available. In these years T.A.B. vaccine was almost universally used, and although inoculation was not compulsory, some 95 per cent. of the British Expeditionary Force were immunized.

	Cases.	Deaths.	Case Mortality.
Inoculated with T.V. or T.A.B.V. ..	2046	12	0·6
Not inoculated	949	14	1·5

The cases and deaths refer to both typhoid and paratyphoid.

These figures show that in the two years 1916 and 1917 the non-inoculated British soldier was between eight and nine times more liable to contract typhoid or paratyphoid than the inoculated soldier, and that, when both contract one or other of these diseases, the non-inoculated soldier is between two and three times more liable to die.

A like comparison in respect to the French Army is similarly favourable to inoculation; and in the German Army it is authoritatively stated that the number of cases of typhoid fever fell at once when inoculation was carried out. Thus anti-typhoid inoculation has proved its value. It saves human life; the severity of attack is generally much lessened; it confers a greater freedom from relapses and complications; convalescence is more rapid; probably the proportion of "carrier cases" is reduced; and even after infection has been contracted, if inoculation is performed early, it reduces the virulence of the attack.

The use of living *B. typhosus* has been recommended for anti-typhoid inoculations instead of cultures killed by heat, with the idea of establishing a greater and a more prolonged immunity than is now possible (a period of less than two years). It has also been ascertained that anthropoid apes can be rendered immune to enteric fever by living cultures of *B. typhosus*, but not by dead. If living cultures are injected, in order to prevent severe general reactions, only non-virulent organisms which have

been subcultured for months or years in a laboratory should be used, and the culture should be heated to 49° C. for one hour before use (Castellani). If virulent strains of *B. typhosus* are used, they should first be sensitized (rendered non-virulent) by mixing them with horse-typhoid immune serum. So far, there are no available statistics as to the comparative results obtained by immunizing with dead or living bacilli respectively.

The success of anti-typhoid inoculation appears to justify the routine inoculation of adolescents between the ages of fifteen and twenty-one in endemic areas.

Paratyphoid Fever.

Paratyphoid fever is a disease caused by one of two bacilli, the paratyphoid A or the paratyphoid B. Both these bacilli resemble very closely the *B. typhosus* in their morphology and general cultural characteristics, but in their behaviour with specific immune sera and in their reactions on certain nutrient media they differ so markedly from the *B. typhosus* and from each other, that there can be no doubt that they are specific micro-organisms, and not varieties of the *B. typhosus* which have become modified by environment. Although paratyphoid organisms have been ascribed as the cause of outbreaks of food poisoning, Bainbridge has shown that such poisonings are due to *B. suipestifer* or *B. enteritidis*. Paratyphoid A is often met with in India, but it is rare in England; and paratyphoid B is best known in Europe. Paratyphoid B is a much less severe and fatal disease than typhoid fever, speaking generally, and paratyphoid A is even milder than B; but there are cases of every degree of severity in both paratyphoid A and B, the milder cases often escaping recognition. Relapse occurs with equal frequency, and the complications are identical in all three diseases.

The diagnosis of paratyphoid fever depends upon bacterial cultures and the specific agglutinative powers of the patient's serum. The disease may be conveyed by the same means as those mentioned in connection with enteric fever, carriers are probably about as frequently met with, and the value of the preventive inoculation which is prepared from the specific organisms is now well established.

Epidemic Diarrhœa.

Diarrhœa is, of course, merely a symptom of very many diseases. But in the sense here understood it means those acute infective attacks of illness of which the diarrhœa is the most prominent symptom, which occur so generally in persons of all ages, but more especially in infants and young children, in urban communities, towards the middle or close of the summer. The death-rate from diarrhœal complaints remains remarkably constant through the winter and spring, but with the onset of hot summer weather in many large towns an extensive outbreak occurs, the chief incidence of which falls upon those at the two extremes of life, or who are enfeebled in health. In a hot, dry summer there is a close correspondence between the curves of temperature and mortality. This epidemic diarrhœa is in many cases of a choleraic nature, accompanied by cramps, spasms, and signs of collapse, and appears to be due to consumption of tainted food, or of impure water, or to the breathing of fouled air. The putrefactive changes which occur in food and fouled water or soil are all more rapid and intense under the influence of a high temperature; and it is quite reasonable to believe that many of these diarrhœal attacks are due to the action of specific bacterial agents, or of their products, when taken into the system.

In some of these cases of acute diarrhœa, the *B. enteritidis* of Gaertner has been found, whilst other cases of epidemic diarrhœa are associated with the *B. enteritidis sporogenes*—a sporing anaerobic organism first isolated by Klein from milk sold in small retail shops, and since found in sewage, in water polluted by sewage, in the excreta of patients suffering from diarrhœa, in horse dung, and in various articles of food. Morgan, working at the Lister Institute for Preventive Medicine on stools of patients suffering from summer diarrhœa in the London Hospitals, found a bacillus of the non-fermenting lactose group to be the predominant organism. This is now known as Morgan's bacillus. But it appears probable that summer diarrhœa is generally due to several associated organisms of the coli type.

Many different terms are employed to designate the disease officially known as "epidemic diarrhœa," and this fact leads to great difficulties in classifying death returns. The terms employed include: diarrhœa, epidemic diarrhœa, dysentery and

dysenteric diarrhœa, intestinal (or enteric) catarrh, gastro-intestinal (or gastro-enteric) catarrh, gastro-enteritis, muco-enteritis, and gastric catarrh. This confusion of terms leads to much discrepancy in the classification of death returns; and early in 1900 the Royal College of Physicians authorized the use of the term "epidemic enteritis" or, if preferred by the practitioner, "zymotic enteritis," as a synonym for epidemic diarrhœa, and recommended the entire disuse of the other terms mentioned above.

Dysentery arises in a very similar way to diarrhœa. The effect of a chill, on which so much stress has been laid, is probably to increase the susceptibility of the system to the poison. It may be that chilling sets up a slight enteritis, whereby the normal resisting power of the lymphoid tissue in the bowel wall is lowered, so that the organisms present in the bowel are enabled to get a foothold and multiply in the intestinal walls. Attacks of dysenteric diarrhœa, with discharges of blood and mucus *per rectum*, are occasionally associated with outbreaks of diarrhœa in this country, and are not uncommon amongst the inmates of lunatic asylums. It is then known as "colitis," and is probably communicable from the sick to the healthy (Mott and Durham).

Although it is unquestionable that dysentery and acute diarrhœa in the vast majority of cases appear to arise *de novo* (independently of the contagion of a previous case), yet it is certain that the diarrhœal evacuations help to spread the disease in certain instances. It has been shown that the infection may be carried in water, and boiling the drinking water has stopped the outbreak.

Some years ago, Dr. Hope of Liverpool conducted an inquiry in order to determine the relative mortality from diarrhœa among infants of artisan parents, classified as follows: First, the entirely breast-fed; secondly, those fed partly on breast milk and partly on artificial food; and, thirdly, the entirely artificially fed. He found that for every death from diarrhœa which occurred among breast-fed infants under three months old, fifteen occurred among those of the mixed class, and that for every death from the same cause among the breast-fed and mixed class combined, twenty-two occurred among the entirely artificially fed.

As previously stated, the disease is mainly one of early child-

hood (0-5 years), 80 to 90 per cent. of the mortality occurring under two years of age; but its incidence is by far the greatest in hand-fed infants, hence female factory labour, by depriving infants of their natural food, is a contributing cause. The attacks are usually extremely sudden in their onset; and that diarrhœa is merely one symptom or feature of the illness is shown by the fact that many of the organs of those who have succumbed are found to be highly degenerated, more especially the kidneys, the liver (fatty degeneration), and the spleen. The lungs, too, are often the seat of pneumonic inflammation.

From the seasonal curve for diarrhœa it appears that the mortality begins to increase about the end of June or in July, according to the temperature of the air, rises rapidly to its maximum some time in August, and falls somewhat less rapidly throughout September and October. The following is a very brief epitome of Dr. Ballard's observations:—

The summer rise of diarrhœal mortality in the large towns does not commence until the mean temperature recorded by the earth thermometer, placed 4 feet below the surface, has attained somewhere about 56° F. no matter what may have been the temperature previously attained by the atmosphere, or recorded by the 1-foot earth thermometer. The maximum diarrhœa mortality of the year is usually observed in the week when the 4-foot earth thermometer attains its mean weekly maximum. The diarrhœa mortality declines with the 4-foot earth thermometer, and this decline takes place very much more slowly than that of the atmospheric temperature or of the 1-foot earth thermometer, so that the mortality from epidemic diarrhœa may continue long after the air temperature has fallen, even into the fourth quarter of the year.

The earth temperature at a depth of 4 feet is valuable as a measure of the cumulative effect of the sun's heat, the variations in earth thermometers following those of a thermometer above ground at an interval of about three or four days. On an average, twenty-four hours are required for the sun's heat to penetrate to a depth of 1 foot, the actual time varying somewhat with different soils.

The soils most favourable to a high diarrhœa mortality are those of sand, gravel, or marl (in which the constituent particles are small but freely permeable by air and water), and which contain organic matter of animal origin from "made ground,"

from manured surfaces, or from soakage of excretal refuse from privies, cesspools, and sewers. The soil must be moist, but the moisture must not be sufficient to preclude the free admission of air between the interstices; the moisture of the soil may arise from surface water sinking into the earth around houses, as well as from capillary attraction of a high subsoil water from below.

Sir Arthur Newsholme's researches point to the following circumstances as determining the incidence of diarrhœa: (1) Towns with water-carriage sewage have, as a rule, less diarrhœa than those practising other methods of removal. (2) Towns with the most perfect scavenging arrangements have least. (3) Towns having the lowest diarrhœal mortalities are situated on impervious soils, though the converse scarcely holds good; and steep gradients favour a low diarrhœal rate. (4) Given two towns, alike in sanitary and social circumstances, the rate is proportionate to the height of the temperature and the deficiency of rainfall, more particularly during the third quarter. (5) There is a general inverse relationship between rainfall and diarrhœa, and a direct relationship between temperature and diarrhœa. (6) The soil is a great factor in the causation of diarrhœa, but its influence may be largely discounted by impervious paving in streets and yards and impervious flooring to houses. (7) The incidence of diarrhœa follows more closely the want of rainfall than the mean temperature of the air; and the efficient washing of streets, swilling of yards, and flushing of sewers reduces it. (8) The disease increases largely in prevalence when the 4-foot earth thermometer reaches 56° F., or when the mean weekly temperature of the air rises to about 63° F.

Other factors conducive to a high diarrhœa mortality are domestic overcrowding, darkness and dirtiness of premises, and the keeping of milk and other foods in underground cellars exposed to telluric emanations, or in pantries liable to the entry of drain or sewer air.

It is also very probable that milk kept in open jugs, and other articles of food, becomes infected with the *B. enteritidis sporogenes* and other organisms, through the agency of flies and of dust containing particles of horse excreta from the streets. Among the more important preventive measures must therefore be placed domestic cleanliness, the prompt removal from dwellings of animal and vegetable refuse (the breeding-place of flies), the protection of food from flies, the exposure of " fly

papers " in the best-lighted parts of rooms, and the more frequent cleansing and watering of streets and yards in dry weather, so as to reduce dust.

Preventive measures are mainly designed to prevent the pollution of the air and soil in and around houses, to encourage the practice of habits of domestic cleanliness, and the protection of food from all sources of pollution. More especially during the summer months should all milk be boiled shortly before use, and the feeding bottles for infants should be kept scrupulously clean. Infants should not be weaned during the hot months, if this can be avoided. All foods should be stored in a light airy place and carefully protected from dust and flies; fruit and vegetables should be thoroughly cleaned before consumption; and no tainted food or unripe or overripe fruit should be eaten. Infantile diarrhœa has been made voluntarily notifiable for several years, during the summer quarter, in Woolwich and Huddersfield. A large proportion of the cases occurring have been notified (the usual fees being paid for notification); and the advice promptly given by health visitors is reported to have furnished excellent results.

The death-rate from diarrhœa and enteritis in England and Wales was at the rate of 0·28 per 1,000 per annum for the ten years 1901-10; for the five years ending 1921 the average rate was 0·07. Doubtless child-welfare activities contributed to this reduction. The deaths under two years of age, expressed as a rate per 1,000 births, furnished the figure of 15·5 for 1921.

House-Flies.—The commonest species of house-fly, and the most predominant in the interior of houses, is *Musca domestica*. Next comes the lesser house-fly, *Homalomyia canicularis*, and then the blue-bottle flies, *Calliphora vomitoria*. The lesser house-fly remains mostly on the wing, flying about with a curious darting movement beneath the gas bracket; it appears earlier in the year than the common house-fly and persists later. The lesser house-fly is closely related to the latrine or privy fly (*Fannia scalaris*), but the latter, although a dangerous disseminator of intestinal diseases in camps, rarely enters houses.

Musca domestica lays its eggs by preference in horse manure, but will also lay in cow-dung, human and other excrement, and ashbin refuse. The usual period from the laying of the egg to the production of the fly is from ten to twenty days. Absence of sufficient moisture, warmth, and food for the larvæ leads to

delayed development or to the production of small and imperfect flies. Flies become sexually mature in from two to three weeks after hatching out. A female fly will lay from four to six batches of eggs, each batch containing from 120 to 150 eggs. The eggs are mostly deposited in collections of dung, human or animal excreta, or refuse heaps.

In two or three days from the eggs being laid larvæ (maggots) can, if necessity arises, leave their food-supply in excreta, and take refuge in the ground, there to undergo pupation. The larvæ under favourable conditions develop to pupæ in from four to six days. The larvæ require warmth and moisture, whilst the pupæ require warmth and dryness. These conditions are best afforded in collections of fresh horse manure undergoing fermentation. Under favourable circumstances rather under fourteen days suffice for the development from egg to fly, and about three weeks from one generation of egg deposition to another. Although all species of house-fly are exceedingly prolific, the numbers in any season are largely affected by such adverse conditions as low air temperatures, heavy rainfall, and absence of suitable material for the development of the larvæ.

A fly will live six weeks, or even longer, in a favourable season. Flies travel with the wind, and under favourable circumstances may traverse a distance of half a mile within an hour.

Flies will, under suitable conditions, survive through the winter; but there is evidence that the seasons are connected for the most part by dormant larvæ in manure-heaps, etc. The spring increase usually commences in April or May in covered collections of fermenting horse manure. The great upward rise in the curve of fly prevalence is usually seen to commence in the first week of July, a maximum being reached some time in August or September, according to the air temperatures prevailing in any particular year. With the commencement of October, a sharp decline in fly prevalence usually sets in. This annual decline is partly due to the onset of frosts, which cause the flies to become lethargic and to remain indoors, so that fewer eggs are laid in dung and refuse, and partly to the destruction effected amongst the larvæ by a fungus the *Empusa muscæ*. Flies may transmit infection by their vomit, their fæces, and by the contamination of their hairy legs and body.

Although in some years in urban populations there is often a considerable amount of correspondence between the curves of

MUSCA DOMESTICA (after Hewitt).

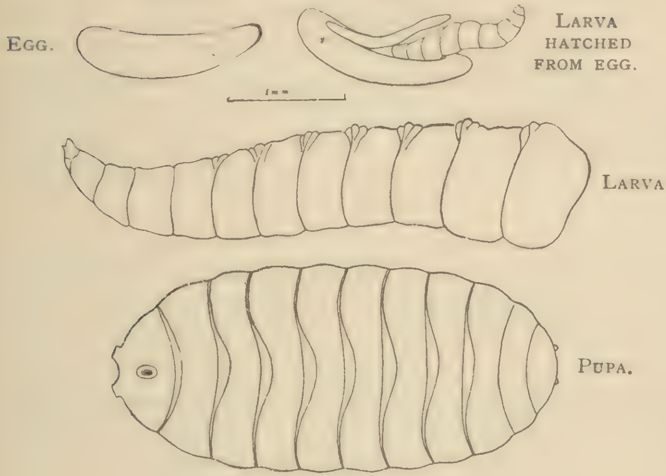


Fig. 80.

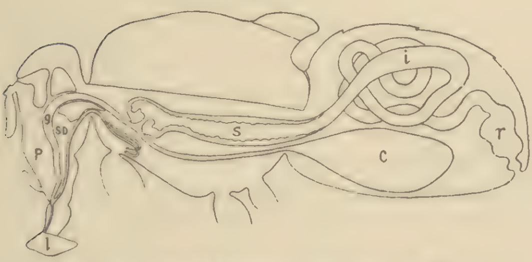


Fig. 81.—Diagrammatic Section of Fly.

p, pump; *l*, labella; *g*, gullet; *s.d*, salivary duct; *s*, stomach; *c*, crop: *i*, intestine; *r*, rectum.

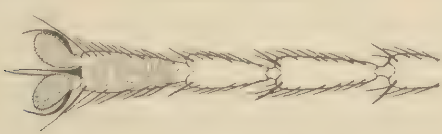


Fig 82.—Leg and Foot of Fly.

Fig 83.—Fly extruding Bubble from Crop.

fly prevalence and of diarrhœa prevalence or mortality, still this correspondence is by no means invariable; and it has been noted on more than one occasion that the diarrhœal curve begins to decline some time before the fly curve begins to drop, whilst the uprises of the two curves in successive years often present dissimilar features or discrepancies, which would hardly be observed if flies stood to diarrhœa in the direct relation of cause and effect.

Of the measures directed against these insects, those which aim at preventing them from gaining access to human dejecta and to persons suffering from communicable disease are of primary importance. As precautions to this end can never be complete, the careful guarding of all food from fly contact is necessarily included in such measures. But with this precaution of *protection* should be combined that of *prevention* (of breeding); and even *destruction* may be called for, especially when there are many breeding facilities close to dwellings.

Among the various methods which have been suggested and applied for preventing collections of horse manure from acting as breeding-grounds of flies, one of the most simple and practical is that of Lieut.-Col. Copeman; and its value has been experimentally demonstrated. Fly larvæ (or maggots) hardly survive long at temperatures above 41° C.; so, if the fermenting refuse in which they breed is closely packed in heaps, the higher temperatures thereby favoured will generally be lethal; and the destruction of the immature flies will be carried out in a manner which does not seriously impair the fertilizing power of the manure.

For the prevention of fly breeding various expedients may be adopted. Where manure or refuse cannot be burnt or buried or lightly spread out, it may be sprayed with crude oil emulsion (Lefroy). This consists of crude mineral oil $5\frac{1}{2}$ pints, soft soap 3 pounds, water about $\frac{1}{2}$ pint. The soft soap is first heated, the water carefully added, and the oil is stirred in while the whole is hot. On cooling, a jelly forms which is miscible with water. It should be employed at the strength of 5 per cent. Borax, about two-thirds of a pound, dusted on to about 10 cubic feet of manure, and 2 to 3 gallons of water subsequently applied by a watering-can with a rose, appears to be less satisfactory, although useful. The covering of accumulations, where they have to be stored, by 12 inches of earth, well beaten down, is another expedient for preventing fly breeding. As to fly destruc-

tion, fly traps are of limited value. Fly papers and wires are serviceable. The best poisonous fluid consists of treacle and water with a little sodium arsenite, in the proportion of 2 pounds to 10 gallons of water, and 10 pounds of sugar or treacle. The arsenite should first be dissolved in a little boiling water. Formalin ½ pint, sugar 10 ounces, milk 1½ pints, water 2½ pints, is another useful poison.

Tuberculosis.

Tuberculosis is a disease to which all warm-blooded animals appear to be susceptible. The degree of susceptibility varies amongst different races of men, and amongst individuals of the same race. The offspring of phthisical parents appear to be born with a certain degree of susceptibility of tissue to attack by tubercle; but this is doubtful, as the occurrence of tuberculosis amongst the offspring of a phthisical parent may be due to continued exposure to infection. It is for this reason that the disease was believed to be hereditarily transmissible. If, however, the disease is congenital at all—*i.e.*, directly transmissible from parent to child—it can only be so to a very trifling extent. Bang has shown that when the calves of tuberculous cows are separated from their mothers and placed under hygienic conditions, they do not develop tubercle in any greater degree than the calves from healthy parents. He found that tubercular lesions at birth are extremely rare, and when present are due to infection through the placental circulation. Investigations by Delépine, Boltz, etc., show no observed tuberculosis in the first, second, and third weeks of life; and Koch has found that guinea-pigs remain healthy if reared apart from tuberculous parents.

The universality of the infection and the extent of human resistance are demonstrated by the circumstance that post-mortem examinations of persons of over forty years of age very generally disclose some old localized tuberculous lesion in the lungs or elsewhere, although such persons have never suffered from the disease in a recognizable form. It is said that tuberculous lesions of one sort or another exist in 90 per cent. of the adult population in highly urbanized communities.

In the opinion of Metchnikoff, in the civilized populations of modern times, large numbers of children in early life are invaded by the tubercle bacillus in small dosage or in attenuated form,

and thereby acquire an immunity in greater or less degree to subsequent invasion by virulent organisms in effective doses.

According to Behring's view, the majority of human tuberculosis is acquired during infancy, and remains latent in the glands until circumstances render the body a suitable soil for the multiplication of the germ.

The Registrar-General includes in the term "tuberculosis," "phthisis," "tabes mesenterica," "tubercular meningitis," and "other forms of tubercular disease and scrofula."

The death-rate from pulmonary tuberculosis for the ten years 1851-60, in England and Wales, was 2·75 per 1,000 per annum; that for the ten years 1911-20 was only 1·10—a reduction of 60 per cent.

If the vital statistics of tuberculosis in this country during the past half-century are studied, it is found that—

1. There has been a marked and progressive reduction in the death-rate, and that the reduction is most marked during the 10-35 years age-period.

2. There has been a still greater reduction (of 50 per cent.) in the death-rate from pulmonary tuberculosis or phthisis, this reduction having been most marked at the several age-periods ranging from infancy up to thirty-five years, and greatest among females.

3. Children under five years of age have a higher mortality from tuberculosis than exists at any subsequent five-year age-period, and this circumstance is due to the greater prevalence of forms other than phthisis. The fact seems to point to the disease being maintained among infants through the agency of infected milk, but some of the increase may be due to a more extended use of the term "tabes mesenterica" in the registration of infantile deaths.

The principal predisposing causes of the disease are: foul air (*vide* pp. 165 and 166); dusty occupations (the male death-rate from tuberculosis of the lungs is nearly half as much again as the female); dampness of site and of premises; dirtiness and darkness of dwelling; poverty with its attendant insufficiency of food and liability to exposure; and alcoholism. Tissue injuries and malformations of the chest are less prominent predisposing causes. The part which "overcrowding" and foul air play in promoting the prevalence of phthisis is well shown at Salford (Dr. Barry and Mr. Gordon Smith's inquiries—data supplied by Dr. Tatham).

Thus, in districts where *all* the houses were built on the vicious system known as "back to back," the phthisis death-rate was 5·2 per 1,000 living; where 56 per cent. of the houses were so built, the rate was 3·6; where 23 per cent. only were so constructed, it was further reduced to 3·3; and, lastly, where there were *no* "back to back" houses—that is to say, where all the houses were provided with some means of light and air both in front and to the rear—the rate was only 2·8 per 1,000. These results are all the more remarkable because, with the exception of the absence of means for through ventilation, the back to back houses on the whole were, in Dr. Tatham's opinion, in better sanitary condition than the other houses. Similar results have been obtained by other observers and by Dr. Darra Mair, of the Local Government Board (see *Report of Medical Officer of the Local Government Board*, 1908-9, p. xix).

Buchanan has shown that the effect of drying the soil, in the case of towns where the level of the subsoil water was previously high, was to greatly diminish (by $\frac{1}{3}$ to $\frac{1}{2}$) the death-rate from phthisis. The connection between phthisis and moisture in the soil, which had been previously pointed out by Bowditch of Massachusetts, was thus confirmed by Buchanan.

The *materies morbi*, the bacillus of tubercle, is contained in the expectoration of phthisical persons. When this is allowed to dry and mingle with the dust of rooms and streets, the bacillus may be inhaled by others, and so infect them. Dujardin-Beaumetz gives a striking history of eleven out of twenty-three clerks in an office being attacked during the course of twelve years, as the result of the introduction of the disease by the first sufferer. The floor of the office was rough, no spittoons were provided, and the air was dust-laden from recent sweeping when the men arrived in the morning. The floor was planed and beeswaxed, expectoration was prohibited except into the spittoons which were supplied, and the cleansing done overnight, as far as possible, with damp cloths, with the result that no further cases occurred.

The infection may also be swallowed, or directly inoculated from discharges. As already stated, milch cows are particularly susceptible to tuberculosis, and in advanced cases of the disease their milk may contain the bacillus (see p. 369). The flesh of bovines, when eaten in a partially cooked condition, may also be capable of conveying the disease.

Dr. Koch has maintained that human tuberculosis differs from bovine tuberculosis, and cannot be transmitted to cattle; and he further holds that bovine tuberculosis is scarcely, if at all, transmissible to man. The former conclusion is based on experiments, in which he failed to infect nineteen young cattle (and subsequently asses, sheep, and goats) with human tubercle bacilli, but he invariably succeeded when he used tubercle bacilli of bovine source. The second conclusion is based upon the contention that if meat and milk introduce the infection into man, there must be in the latter primary tubercular lesions in the intestines, and these are believed to be rare.

Dr. Koch's views have not met with much support from other authorities, but owing to his great position as a bacteriologist, the English Government considered it desirable to refer the whole question to a Royal Commission, which has issued several reports.

The conclusions arrived at by the Royal Commission appointed to inquire into the relations of human and bovine tuberculosis are given in the Second Interim Report (1907) as follows:—"There can be no doubt but that in a certain number of cases the tuberculosis occurring in the human subject, especially in children, is the direct result of the introduction into the human body of the bacillus of bovine tuberculosis; and there also can be no doubt that in the majority at least of these cases the bacillus is introduced through cow's milk. Cow's milk containing bovine tubercle bacilli is clearly a cause of tuberculosis and of fatal tuberculosis in man."

Out of sixty cases of human tuberculosis investigated by the Royal Commission, in fourteen, or 23 per cent., the tuberculous material obtained from the cases, when injected subcutaneously into calves in the form of emulsions, either prepared directly from the original material, or indirectly, from the tuberculous organs of guinea-pigs infected with that material, was found capable of producing a generalized progressive tuberculosis in the experimental animals. The Commission found that this generalized progressive tuberculosis was due to the virus containing the bacilli of bovine tuberculosis, and that the vira containing the bacilli of human tuberculosis, in which a bovine source could be excluded, were far less virulent to bovine animals, and could not set up in them a generalized progressive tuberculosis.

Out of the sixty cases of human tuberculosis investigated by

the Royal Commission, twenty-eight possessed clinical histories indicating that in them the bacillus was introduced into the body through the alimentary canal. Of these twenty-eight cases, thirteen, or 46 per cent., were shown to contain the virulent form of organism, which alone produces in bovine animals a generalized progressive tuberculosis, and which was therefore identical with the bacillus of bovine tuberculosis.

The above facts seem to indicate that a very considerable proportion of the human tuberculosis contracted by ingestion and primary invasion of the abdominal organs, is due to tubercle bacilli of bovine source.

The following statement has been specifically issued by the Royal College of Physicians "in view of the exaggerated fear of the infectivity of pulmonary tuberculosis entertained by the public":

The Infectivity of Tuberculosis.

1. Tuberculosis is an acquired disease, but certain constitutional types may be inherited which render the patient specially susceptible to infection, and there is reason to think that such susceptibility is an inherited character.

2. The infective agent is the tubercle bacillus. This may be contained in the various discharges and excreta of the patient, and especially in the sputum of those suffering from pulmonary tuberculosis. No discharge is infective unless it contains the tubercle bacillus.

3. Cases of tuberculosis of bones, glands, and internal organs from which there is no discharge or which do not furnish any excretion, and cases of arrested pulmonary tuberculosis, have never been proved to be infectious.

(By arrest is here meant that all the symptoms and physical signs of activity have disappeared, and the sputum has either ceased or no longer contains tubercle bacilli.)

4. The means by which tubercle bacilli may enter the body are:—

(*a*) *By inoculation* through a wound or abrasion of the skin. This has occasionally occurred to workers in laboratories, post-mortem attendants, and others dealing with tuberculous material, and is presumably the way in which lupus is acquired.

(*b*) *By inhalation.* Susceptible animals are readily infected by the inhalation of air containing tubercle bacilli, whether in droplets or suspended as fine dust, but in the spread of the disease among human beings the latter appears to be the more important means of infection. The sputum or other discharges, whether on soiled handkerchiefs, linen, garments, or elsewhere, when dried, may become pulverized, and in this condition may be readily dispersed in the air of a room. That droplets of sputum are less important agents of infection is suggested by the fact that the incidence of consumption upon the staff, nurses, and others engaged in hospitals for the

treatment of tuberculous disease, where all discharges are carefully disposed of, is not above the average in the general population.

(*c*) *By swallowing*. Dust infected by the tubercle bacillus may be conveyed to food and so enter the alimentary canal; or infection may occur more directly in the act of kissing or by consumptive and healthy persons using the same food utensils. As about 10 per cent. of the milk supplied to large cities contains tubercle bacilli derived from infected cows, this avenue of infection is particularly important in the case of children. The bovine tubercle bacillus is more commonly responsible for tuberculosis in young children than in adults, but the proportion of cases due to it varies very much in different localities.

There is no evidence that tuberculosis can be conveyed to others either by the breath alone, or by emanations from patients, or by their garments, unless soiled by dried sputum or discharges.

5. The spread of tuberculosis is favoured by uncleanliness, overcrowding, and imperfect ventilation, and is hindered by the opposite conditions. Experience in hospitals and other institutions where the following precautionary measures have been thoroughly carried out indicates that by such measures the risk of infection is reduced to a minimum, namely—

(*a*) The careful disposal and disinfection of the sputum and other discharges.

(*b*) The disinfection or destruction of soiled handkerchiefs, clothes, and linen.

(*c*) The removal of dust by frequent moist cleansing of the floors, walls, etc., of the rooms.

(*d*) The supply of abundant air space, and free ventilation with fresh air.

No risk is incurred by living in the immediate neighbourhood of institutions for the treatment of tuberculosis which are properly conducted.

Professor Lyle Cummins thinks the occurrence of tuberculosis in various types of population is largely explainable by the action and interaction of infection and bodily resistance. In areas where, owing to some geographical or other barrier to intercommunication, the population has remained comparatively isolated from the rest of mankind, cases of tuberculosis tend to be rare or absent. This absence or rarity is accompanied by a very low percentage of positive cutaneous (von Pirquet) reactions to tuberculin, due to the absence or rarity of the tubercle bacillus. The inhabitants of such areas show, however, when brought into contact with infection, an extreme degree of susceptibility to tuberculosis, the clinical manifestations of attack being characterized by an absence of fibrotic reaction, a tendency to rapid generalization of the disease, and a speedy fatal ending.

The phenomena of the disease in civilized communities are best explained on a theory of active immunity acquired by contact with the tubercle bacillus, which is so abundantly present in almost all classes, that a majority of children under fourteen years of age have already acquired definite tuberculous lesions, as shown by the following table:—

FREQUENCY OF TUBERCULAR LESIONS IN CHILDREN AT POST-MORTEM EXAMINATION.

0–3 months	4 per cent.	3–4 years	60 per cent.
4–6 ,, ...	18 ,, ,,	5–6 ,, ...	56 ,, ,,
7–12 ,, ...	23 ,, ,,	7–10 ,, ...	63 ,, ,,
1–2 years	40 ,, ,,	11–14 ,, ...	70 ,, ,,

These lesions in early childhood are often due to infection with the bovine bacillus; but whether arising from bovine or human sources, they appear to confer immunity more or less to the generalized and rapidly fatal forms of tuberculosis, which are not common until after puberty.

Dr. John Brownlee, in his investigation for the Medical Research Council into the epidemiology of phthisis in Great Britain and Ireland, has drawn the conclusion that three types of phthisis exist—a young adult type, having its maximum mortality amongst males between the ages of twenty and twenty-five years; a middle age type, with a maximum mortality among males between forty-five and fifty-five; and an old age type, causing a maximum mortality amongst males between fifty-five and sixty-five. These three types are very unequally distributed throughout the country. The young adult type is most marked in the unprotected communities or virgin soils—*e.g.*, the Shetlands, Highlands of Scotland, Ireland, Norfolk, North Wales, and Devon. The middle age type has its best example in London, but is also seen in Lancashire and Northumberland; whilst the old age type is noteworthy in Cornwall combined with a high young adult mortality. In Cornwall there is a virgin soil allied to the occupation of the tin-mining industry which induces a high mortality at the higher ages. As a rule, where the young adult type prevails, the middle age type is rare; where the middle age type is common, the young adult type is seldom seen. The old age type is found under special circumstances only, and usually in combination with the young adult type. There is high positive correlation between fatal tuberculosis in children under five years and the prevalence of

the middle age type of phthisis. This may mean that the tuberculous lesions acquired in childhood, whilst protective against the young adult type of phthisis, fail to secure immunity against the middle age type, which is especially associated with urban conditions of life—namely, overcrowding in houses and workshops, industrial fatigue and stress of competition, combined with constant exposure to reinfections.

The theory of an "inherited disposition to tuberculosis" is no longer necessary to account for the facts of multiple invasion in families where one of the parents is tubercular, if infection and bodily resistance are taken into account; and all the phenomena of variation in clinical type, case mortality, age and sex distribution, locality and occupation, characteristic of tuberculosis in a highly organized community, are explicable in terms of infection and resistance and the acquisition of immunity in higher or lesser degrees.

Professor Calmette is of opinion that virulent tubercle bacilli may be disseminated by apparently healthy carriers, their tubercular lesions being inconspicuous and limited to a few glands; but the more generally accepted view is that only cases with tubercle bacilli in the sputum, or tubercle bacilli in the discharges from sinuses and open sores are really dangerous.

During the years of the Great War—1916 to 1918—the death-rate from tuberculosis rose considerably in England and Wales, but affected principally in its greater mortality females from twenty to thirty-five years of age. It seems probable that this increase of mortality was due to the large numbers of young women who came under industrial conditions in the manufacture of munitions of war, and being for the most part unaccustomed to sedentary work in factories, to long hours, and the stress and fatigue of mechanical work, suffered thereby in health, and offered less resistance to the invasion of the tubercle bacillus, whilst more exposed to its onset. The excessive mortality amongst young adult women reached its maximum in 1918, but declined considerably in 1919, as the demobilization of men in the army led to increasing replacement of women by men in all industrial occupations.

The effect of the war on phthisis mortality in males is not capable of accurate determination, owing to the continually varying numbers in military and civil life as the war proceeded.

The rejection of men for the army who showed signs of tuberculosis necessarily led to the male civil population containing an undue proportion of phthisical subjects; but the stress of service conditions caused tuberculosis to develop in many men, who in civil life would have escaped, and whose illness has been allowed to rank as due to war service, even although probably many of them on being accepted as recruits had already latent tubercular foci somewhere in their systems.

Shiga, of the Kitasato Institute for Infectious Diseases, Tokio, Japan, advocates protective inoculations in the earliest stages of tuberculosis with a tuberculosis sero-vaccine prepared by him. Persons who react to the von Pirquet cutaneous test, but have no definite physical signs of tuberculosis, children with cervical adenitis, children in whom radiography shows a swelling of the hilus (bronchial) glands at the roots of the lungs, those who have been exposed to infection, and those in the pre-tubercular stage, as shown by anæmia, debility, chronic catarrh and cough, and slight fever, are all likely to benefit by this form of treatment combined with protective inoculation, as shown by increase of body weight, disappearance of fever and suspicious signs in the lungs, and subsequent complete restoration to health.

The injections of tubercle bacilli sero-vaccine are given once a week for four months, the strength being gradually increased, the last injection containing living organisms (non-virulent sensitized tubercle bacilli). In Shiga's opinion infection with tubercle bacilli takes place in most cases during childhood, followed by a period of latency of several years preceding the development of pulmonary tuberculosis. It is during this period of latency that treatment should be begun, with a view to arresting the tubercular process by the creation of artificial immunity, before the disease has arrived at the so-called "open" stage, when not only is the possibility of arrest much more difficult to accomplish, but the danger of infection to others is already established.

Little is known at present in this country of Shiga's methods, but it is obvious that if his statements are well founded as to the results likely to be obtained, the prophylactic treatment of all children during school age, who show signs suggestive of tuberculosis, might have an enormous influence in reducing the prevalence and mortality of tuberculosis in the adult. This is

a work which is now capable of accomplishment in this country by the highly trained and skilled school medical service existing in every important centre of industry.

Under the term "pseudo-tuberculosis" a whole series of lesions, similar to those induced by the *B. tuberculosis*, is included. This condition, which is rare in man, is mostly caused by some aspergillus or streptothrix, and more rarely by nematodes; but in either case grey nodules and caseating tubercles present appearances very liable to be mistaken for tuberculosis, both in quadrupeds and birds. A *B. pseudo-tuberculosis* was isolated by Pfeiffer from some of these cases, and more recently Klein has found the same bacillus in water, milk, sewage, and sewage effluents. It is pathogenic for animals, producing lesions like the *B. tuberculosis*, but no giant cells are found in them. Animals are killed by it sooner than by the tubercle bacillus. The disease known as actinomycosis is sometimes mistaken for tuberculosis, and vice versa.

The preventive measures which may be taken to reduce tuberculosis may be summarized as—

1. The compulsory notification of phthisis, as now required under the Public Health (Tuberculosis) Regulations, 1912.

The notified case should be visited by the Medical Officer of Health, or someone acting on his behalf. A careful note should be made of the home conditions, and the patient should be instructed in proper methods of collecting and disposing of the sputum. The patient should be urged to sleep in a room by himself, or at any rate in a separate bed, and to maintain a good state of ventilation, by keeping the window of his day-room and sleeping-room always open. Advice should be given as to diet, clothing, protection from chills and exposure, and, if the patient remains at work, how to obviate any risk of infecting fellow-workmen. At the same time, other members of the patient's family and "contacts" in the same house should be seen, and, if necessary, their state of health should be inquired into. "Suspects" should be sent to the local tuberculosis dispensary to undergo a thorough medical examination.

The patient should be advised as to how to obtain sanatorium benefit from the County Conucil or County Borough Council, and should be urged to seek advice and treatment at the local tuberculosis dispensary.

2. The removal of those conditions of domicile and of occupa-

tion which are known to promote the incidence of the disease, including the regulation of certain dusty trades.

3. The diffusion of knowledge (by medical men, leaflets, etc.) regarding the nature and modes of spread of the disease, and the precautions which should be taken in order to prevent its extension.

A continuous supply of fresh air, admitted through the window, can be tolerated night and day if either of the following arrangements is made:

(*a*) Raise the lower sash of the window for 6 inches, and then closely fit, into the open space below, a wooden board. Air then enters where the upper and lower sashes overlap, without causing a draught.

(*b*) Open the window at the top for 6 inches and fix a muslin curtain, or nail a piece of muslin, so that it covers the open part. By this device draughts are very much reduced.

(*c*) A screen reaching to a little above the head of the sufferer can be placed alongside the upper part of the bed, on the window side. No draught will then be felt by the sufferer.

4. The testing of sputum and other suspected discharges, and of milk, meat, etc., supposed to be tuberculous, by the sanitary authority free of charge.

5. Local authorities to undertake, without charge, the disinfection of houses recently occupied by phthisical persons.

6. The establishment of sanatoria and isolation accommodation for the cure of phthisical patients, and the isolation of those who are a distinct source of danger to fellow lodgers or workers. Newsholme has pointed out that the death-rate from phthisis has declined to the greatest extent in those countries in which the ratio of institutional to domestic relief has been highest; and that the admissions to workhouse infirmaries, hospitals, and lunatic asylums have greatly increased in this country during the past thirty-five years.

7. The enforcement of measures against spitting in public conveyances and in places of public resort.

8. The efficient sanitary supervision of dairy farms, dairies, and milkshops. The periodical veterinary inspection and testing (by tuberculin) of milch cows, and the removal of tuberculous animals from the herd. The prohibition of the sale of milk of cows affected with tuberculosis.

9. The proper inspection of meat in public abattoirs, and the adoption of due precautions for the control of imported meat and milk.

Sanatoria for Consumptives.

Although there has been a tendency to exaggerate the good results to be derived from the sanatorium treatment of consumption, the value of the treatment is very considerable, and has been abundantly testified to, more particularly in Germany, where more than a hundred sanatoria exist. But it is necessary to make a careful selection of the cases to be admitted, if the best results are to be obtained from the expenditure entailed. Cases of recent origin with limited lesions and little or no fever may be expected to derive considerable benefit from the sanatorium treatment, but a carefully selected chronic case may be found to benefit also, sometimes more so than some of the early and acute cases. Another necessary condition of success is the retention of the patient for a sufficiently long period (six months, on the average) before he is discharged, and even then regard must be had to the fact that he is very liable at any time to a relapse. With a view of reducing this risk it is often necessary that the individual should not return to his old occupation and environment; and, therefore, it seems desirable in connection with such institutions that there should be an After-Care Committee, whose duty should be to keep in touch with the discharged individual, to advise him, and (where necessary and possible) assist him in obtaining suitable outdoor occupation. Failure to comply with the above provisions may result in the sanatorium treatment proving a costly failure.

The general features of the sanatorium treatment are as follows: As much as possible of the life of the patient is spent in the open air; at certain stages absolute rest is required, at others graduated exercise; careful and generous feeding is an important part of the treatment; massage, baths, and cold sponging are also necessary for certain cases; and the educational and disciplinary effects should be such as to continue of lasting value to the patients. It is necessary that the patients should be under almost constant medical supervision; they should be carefully classified, and most of them should be visited three times daily, the temperature taken, and directions given with reference to food, exercise, etc., in accordance with their condition. Therefore there should be one medical man to not more than 100 patients. It is furthermore desirable in connection with such institutions that there should be provision in the grounds for some kind of labour, especially when the sanatorium is a poor-class one. The employment of suitable patients in a little gardening, poultry farming, bee-keeping, or other light labour, not only does something to prevent them from becoming lazy, but serves to train them in outdoor pursuits, and this training they can sometimes turn to account after leaving the sanatorium. At the Frimley Sanatorium of the Brompton Hospital for Consumption, the former Resident Medical Officer, Dr. Patterson, introduced a system of graduated labour, by which patients can be led on, stage by stage, to undertake the most laborious forms of manual work such as is ordinarily performed by navvies. This graduated system of labour has been found to have an important influence on treatment and cure of the disease, the effect of the graduated exercise being to cause auto-inoculation—that is to say, the tubercular toxins, as the result of

exercise, are introduced into the systemic circulation, and tend to raise the resisting power of the individual, in the same way as do inoculations of dead bacilli and their products in "vaccine treatment."

The site of a sanatorium is a matter of prime importance. The ideal site is the southern slope of a hill, sheltered from the north and east winds by rising ground or trees. There should be a wide clearing of any trees on the south side, and to a less degree on the other aspects. The aim is to obtain a site with pure air, abundant sunshine, clean and dry soil, a low but equable temperature, and protected from winds. The site should be of easy access, not too far from a railway station, and well away from a high-road and the dust which may arise from it. For an institution of 100 beds it is desirable to have 100 acres of land, in order that there may be sufficient ground to provide protected walks for the patients, for keeping cows, for growing vegetables, and for providing work for convalescents. Dotted about the grounds there should be a large number of seats. Probably 100 beds are sufficient for any one institution; and not more than six beds should be placed in one ward. In the more expensive sanatoria a large proportion of the bedrooms are single bedrooms, which is of course an ideal arrangement. The ideal sanatorium consists of a number of isolated chalets surrounding the central administrative block, each chalet to accommodate one patient. The chalet need only be of the size of a small room, with an added verandah. It should be raised from the ground and provided with windows in all four directions. A very good arrangement is to have two-thirds of the accommodation provided in chalets, and the remainder in one main building. The main building should have balconies with verandahs and French windows, so that the beds may be wheeled out on to balconies, and the bedrooms of at least 750 cubic feet capacity with floors made of teak or oak on cement concrete. The linoleum frequently used in Germany and elsewhere to cover the floors is not satisfactory. Washable distemper walls with a smooth surface are desirable; the lighting should be by electricity, and the warming by hot water pipes. Electric fans for ventilation are sometimes desirable in winter.

In a Memorandum of the Local Government Board (1913) it is recommended that in the construction of inexpensive buildings for sanatorium purposes the following materials may be employed: Timber-framing, weather-boarded and creosoted, or covered with corrugated iron or other suitable material, such as asbestos sheeting, and lined internally with lath and plaster, fireproof sheeting, etc. These may be erected on a concrete platform, which may also form the flooring of the wards and verandahs, the floors to be finished in cement and covered with linoleum.

In connection with a sanatorium provision must be made for disinfecting and incinerating infected material, and a dispensary, pathological laboratory, consulting room, mortuary and post-mortem room, laundry and drying room, baths, operating theatre, library, committee room, recreation room, private dairy, ambulance, and electrical engine-house have all to be provided. It will be seen,

therefore, that a sanatorium is of necessity an expensive provision; but all arrangements for the treatment can be made on quite a satisfactory basis at a cost of from £100 to £200 a bed, and there is no occasion to spend the very large amounts which have often been spent on costly structures in this country.

Poverty, drink, and ignorance of the laws of hygiene are largely responsible for the prevalence of consumption, and it is not easy to exaggerate the influence of badly ventilated, dusty, and overheated rooms, whether in the dwelling or the factory, in inducing the disease and favouring its spread. Having regard to the considerable decline in consumption during past years, which decline is to be attributed to better wages, better dwelling-houses, and increased temperance, we must attach a prime importance to the provision of more healthy dwellings for the poorer classes and a more general practice of the laws of health, and a subsidiary importance to the provision of sanatoria. Even more important than the provision of sanatoria is the provision of the means for the removal to a place of safety of advanced cases among the poorer people, for nothing can exceed the danger of infection which comes from the advanced case nursed at home in bad surroundings, to which he contributes a maximum of infection day by day. The care of advanced cases is not incompatible with the provision of sanatoria and other measures; and, of course, the recovery of a sufferer who is detected in the early stages of the disease prevents the occurrence later on of one of these active foci of infection.

The sanatorium is an important link, but only a link, in a comparatively long chain of preventive measures. By itself it can do little to prevent consumption; with the working classes it cannot accomplish much in the way of cure of the disease; the disease will often be arrested, but if the individual is allowed to return to those conditions under which he contracted the disease he will almost certainly relapse. The fact that over 30 per cent. of the deaths from consumption occur in Poor-Law institutions is testimony of the pauperizing effects of the disease. As almost all the sufferers are admitted at a late stage of the disease, these institutions have doubtless played a useful part in isolating cases which are the most dangerous to others.

Tuberculosis Colonies.

Colonies and workshops have been advocated for post-sanatorium cases as providing a natural transition from the exercise treatment, now carried out in most sanatoria, to the resumption of normal life. In order that a worker may not return directly from a sanatorium to an unhealthy home or occupation, where he is almost sure to relapse, a complete change to the simple and healthy life of the country is recommended. In the industrial colony the worker may learn a new trade, if this is considered necessary, or may work at his old trade, the latter being the preferable course, as it is only very exceptionally that a grown man can acquire such knowledge and skill in a new trade as to be able to make a living from it. In any case, the work is carried on under the best hygienic conditions, and with the periods of rest and recreation needful for the man's condition of health. Medical advice is available if required, and the best technical advice on the trade aspects of the work is at hand. It is very seldom that a man accustomed to more or less sedentary work indoors can take up the work of an agricultural labourer. The work is too hard and too monotonous, and the life is too isolated for a man accustomed to town life. There are, of course, other open-air occupations, but they are for the most part picked jobs, which are not easy to find.

The rôle of the industrial colony is to provide a training under medical control for a period of six to twelve months for post-sanatorium cases with a good prognosis, so as to form a transition stage between sanatorium treatment and the resumption of active employment, which must be sought outside the colony. It is estimated that 80 per cent. of the colonists will be able to provide for themselves on leaving. The colonist either learns a new trade, or preferably re-educates himself in his old trade, being chiefly guided by economic conditions. The colony cannot be self-supporting, as the output of the best managed is less than half of what can be done by healthy workers in the same trades, so that the colony must be subsidized. For the residual 20 per cent. of the colonists, who cannot return to outside normal life, some form of permanent industrial settlement is desirable, where men can be joined by their wives and families, and can be allotted cottages on the estate in close proximity to their work.

Tuberculosis Dispensaries.

The Tuberculosis Dispensary is an important provision in the campaign against tuberculosis. Such a dispensary should be in effective touch with the homes of the sufferers, and should be linked up with the Municipal Public Health Department, a sanatorium, a hospital for advanced cases, and an after-care association. It should be central, and constitute itself a bureau of information upon the disease, and a link with all institutions and local provisions for dealing with infected persons. It must provide nurses and health workers to visit the homes and to instruct the occupants, and supply the means for the bacteriological examination of sputum; it should dispense necessary medicines, sputum bottles, disinfectants, and, where the patient's condition seems to warrant it, even foodstuffs and articles of clothing. It should therefore enlist the support of local charitable organizations.

A Tuberculosis Dispensary System was first established in this country in Edinburgh, in 1887. The aim of a Dispensary System is to secure that not a single case of tuberculosis shall occur unobserved or remain uncared for in the community. The patient is either treated directly by his medical adviser, or at the dispensary, or is sent for treatment to the proper institution. The essential feature of the system is the provision of the services of a doctor, who not only sees the patients when they come to his dispensary, but also visits them in their homes, advises as to hygienic and precautionary measures, and examines other members of the house for early signs of consumption. He is assisted in this home visiting by a trained nurse, whose duty it is to make periodical visits with the object of insuring that the patients who are allowed to remain at home under treatment are following out the instructions they have received. But the dispensary is not an isolated unit. It provides the means for classifying the cases and for securing for each the most appropriate treatment, whether it be in a sanatorium, a hospital, an improvised shelter, a home for advanced cases, or the patient's dwelling. The co-operation of the sanitary authority, the Poor-Law authority, the local hospitals, churches and chapels, and various charitable agencies, is obtained; and in order that there may be no interference with the work of other medical men, no patient previously under treatment is treated without the

sanction of those by whom he has been attended. Moreover, all treatment is free; but persons who are found able to pay for treatment are referred to private practitioners. The cases requiring medical relief are referred to the Charity Organization Society or other suitable agency.

In connection with the work of the Tuberculosis Dispensary it is desirable to obtain the assistance of a small After-Care Committee to secure for patients who have been discharged from sanatoria, or who have received satisfactory treatment at the dispensary, that advice and help about their future life and work shall be given. This necessity for after-care is set out in the Interim Report of the Departmental Committee on Tuberculosis. In addition to giving advice, in some cases an endeavour should be made to obtain suitable occupation, to combat the fear of infection often felt by employers and fellow-employees, and to prevent relapses.

But apart from the provision of dispensaries, the need of many hospital beds for advanced, emergency, observational, educational and surgical cases is very great. These may be provided in separate pavilions at isolation hospitals in conveniently accessible sanatoria or in special hospitals, while arrangements may be made with general hospitals for receiving operative and other special cases.

The Grancher system of placing out in healthy rural families children whose lives are in jeopardy through living with tuberculous relatives has borne very good results.

The Public Health (Tuberculosis) Regulations, 1912.

These are Regulations made by the Local Government Board under the powers conferred by Section 130 of the Public Health Act, 1875, as amended by the Public Health Act, 1896.

Every Local Authority is required to provide forms of notification as set out in Schedule A of the Regulations, and to supply them to the medical practitioners within its district. Every medical practitioner shall, within forty-eight hours after first becoming aware that a person whom he is attending is suffering from tuberculosis, notify (Form A) the Medical Officer of Health for the district within which the place of residence of the person is situate at the date of notification. A medical practitioner is not required to notify, if he has reasonable grounds for believing that the case has been already notified under the existing or previous Regulations. When the person is an in-patient at an institution, the notification must be sent to the Medical Officer of Health of the district in which the usual place of residence of the patient is situate. Every school medical inspector must

notify (Form B) at the end of each week all cases of tuberculosis of which he has just become aware, in the course of inspections made by him during the week, of children attending public elementary schools. The notifications are to be sent to the Medical Officer of Health of the district within which the places of residence of the children are situate. The medical officer of a Poor-Law institution or of a sanatorium, in addition to being required to notify new cases (Form A), must also notify weekly (Form C) all cases of tuberculosis admitted during the week, which have been previously notified, to the Medical Officer of Health of the district within which the places of residence of the persons notified are situate; and under Form D he must notify all cases of tuberculosis discharged during the week, other than cases transferred to a Poor-Law institution or a sanatorium, to the Medical Officer of Health for the district within which the places of destination of the persons notified are situate.

The diagnosis of tuberculosis must not be based solely on the results of tuberculin tests.

The fees for notification are chargeable quarterly to the Local Authority for the district within which the place of residence or place of destination of the person notified is situate. The fees for Form A are 2s. 6d. to a private practitioner, and 1s. to the medical officer of a hospital, of a Poor-Law institution, or a District Medical Officer. For forms C and D the medical officer of a Poor-Law institution is entitled to 1s. for the first name on each list, and to 3d. for each additional name. School medical officers and medical officers of sanatoria receive no remuneration for notifying.

All notifications and documents as to notified persons are to be regarded as confidential. The Medical Officer of Health is required to forward on notifications of persons not residing in his own district, to keep a register of all cases in his district, and to forward a weekly list to the Medical Officer of Health of the county. The Medical Officer of Health, or an officer acting under his instructions, shall make such inquiries and take such steps as are necessary or desirable for investigating the source of infection, for preventing the spread of infection, and for removing conditions favourable to infection. A Local Authority, on the advice of their Medical Officer of Health, may supply all such medical or other assistance, and all such facilities and articles as may reasonably be required for the detection of tuberculosis, for preventing the spread of infection, and for removing conditions favourable to infection; and for that purpose may appoint such officers, do such acts, and make such arrangements, as may be necessary. The Local Authority may also provide and publish or distribute suitable summaries of information and instruction respecting tuberculosis and the precautions to be taken against the spread of tubercular infection.

Nothing is to be done under the Regulations which renders the notified person, or anyone in charge of such person, or any other person, liable to a penalty, or subjects the notified person to any restriction, prohibition, or disability affecting himself or his employment, occupation, or means of livelihood, on the ground of his suffering from tuberculosis.

The penalty for a contravention of the Regulations is a fine not exceeding £100, and, in the case of a continuing offence, a further penalty not exceeding £50 for every day during which the offence continues [Public Health Act, 1896, Section 1 (3)].

The National Insurance Act, 1911.

Under this Act "insured persons" who are suffering from tuberculosis, in addition to the other benefits provided for in the Act (medical, sickness, and disablement), are entitled to receive sanatorium benefit, which is defined as being "treatment in sanatoria or other institutions or otherwise." By Section 16, for the purpose of administering sanatorium benefit, Insurance Committees shall make arrangements, to the satisfaction of the Insurance Commissioners, for providing treatment for insured persons suffering from tuberculosis in sanatoria and other institutions (hospitals, convalescent homes, homes of rest, etc.) with persons or Local Authorities (other than Poor-Law) having the management of such sanatoria or institutions, which are to be approved by the Local Government Board. Treatment may also be given otherwise than in sanatoria or institutions by means of dispensaries or by medical practitioners in a manner approved by the Local Government Board. For defraying the expenses of sanatorium benefit the annual sum of 1s. 3d. for each insured person resident in the county or county borough is set aside out of the funds accruing under the Act, and the sum of 1d. in respect of each such person out of money provided by Parliament. But the latter amount may be retained in whole or in part by the Insurance Commissioners for the purposes of research.

Out of the 1s. 3d. available annually the sum of 6d. has been allotted for the purpose of payment to medical practitioners on the "panel," who attend and treat insured persons suffering from tuberculosis in their own homes, so that the sum of 9d. remains for the purposes of sanatorium and other institutional treatment (hospitals, dispensaries, homes of rest, etc.). An insured person is not entitled to sanatorium benefit unless recommended for such by the Insurance Committee.

The Insurance Committee for any county or county borough may extend sanatorium benefit to the dependents of insured persons, or to any class of such dependents. By Section 17 (2), if in any year the amount available for defraying the expenses of sanatorium benefit is insufficient to meet the estimated expenditure, the Insurance Committee may transmit to the Treasury and the County Council or County Borough Council a statement of accounts, and the latter bodies may sanction the expenditure, and will then be liable to make good (Treasury one-half, County Council or County Borough Council one-half) the expenditure on sanatorium benefits in excess of what is available from the funds of the Insurance Committee. The above section applies to the treatment of insured persons and their dependents; but the Government has decided that money shall be available from the Treasury grant for the treatment in addition of non-insured persons, as if they had been included in Section 17. By Section 22, the Council of any borough or urban or rural district may agree with

the County Council to repay to the latter body the whole or any part of the money payable by the Council in accordance with the provisions of Section 17, so far as that money has been or will be expended on medical or sanatorium benefits for the inhabitants of the borough or urban or rural district.

Section 64 (1) of the National Insurance Act, taken with Section 16 (1) (*b*) of the Finance Act, 1911, makes available from the National Treasury a sum of £1,500,000 for the purpose of the provision of, and making grants in aid to, sanatoria and other institutions in the United Kingdom.

Under the National Insurance Act of 1920, Insurance Committees are no longer required to provide sanatorium and hospital treatment for insured persons, the necessary provision being now made by the Councils of counties and county boroughs.

A Departmental Committee was appointed by the Government in 1912 to consider and report upon the problem of tuberculosis in the United Kingdom in its preventive, curative, and other aspects, so as to guide the Government and local bodies in making or aiding provision for the treatment of tuberculosis in sanatoria or other institutions or otherwise. The Committee recommended the establishment of tuberculosis dispensaries, the intention being that each dispensary should be the local centre of expert diagnosis and treatment acting in co-operation with the private practitioners of the district. The dispensary would also serve as a clearing-house through which all persons suffering from tuberculosis should be passed; and it should have important functions as a centre for the examination of "contacts," the "after-care" of patients discharged from institutions, and for the dissemination of information with regard to tuberculosis.

The Committee were of opinion that one dispensary would be required for every 150,000 to 200,000 of the population in urban districts, but that in rural districts only a smaller number of persons could be served. They recommended that capital grants from the Treasury should be made up to four-fifths of the amount required for the provision and equipment of dispensaries, provided that this sum should, generally, not exceed £1 per 750 population, or an average of £240 per dispensary. With regard to sanatoria, the Committee considered that most probably one sanatorium bed per 5,000 population would be required for the United Kingdom, and the same proportion for the purposes of observation, training, and isolation, and that in the interests of economy, an individual sanatorium should not contain less than 100 beds. They recommended that capital grants from the Treasury up to three-fifths of the cost per bed (estimated at not exceeding £150) should be made for the provision of additional sanatorium and hospital beds for adults, provided that the total sum should not exceed £90 per bed.

The recommendations of the Committee with regard to the grants of money from the Treasury have been adopted by the Government.

The two Reports of the Committee enter very fully into the various questions connected with the functions of tuberculosis dispensaries, the accommodation to be provided, the staffing (including the appoint-

ment of tuberculosis officers), the cost, etc. The provision and administration of sanatoria, hospitals, and other institutions for dealing with all varieties of tubercular disease are considered and described, together with the methods of prevention suitable for dealing with the disease as arising from food, infection by tuberculous persons, etc. For the purpose of securing the proper organization of comprehensive, efficient, and economical schemes, it is recommended by the Committee that the administrative area should generally be that of a county or county borough, or in some cases a group of counties and county boroughs.

Epidemic Influenza.

Influenza in its epidemic form is an infectious disease, and should be classed with specific fevers. Nothing very definite is known of the etiology of influenza, but it does not appear to show a preference for any particular localities, nor to follow always the same channels of communication, and it has prevailed independently of season, climate, and weather. The disease does not seem to associate itself especially with insanitary surroundings, and the incidence upon the poor is generally lighter than upon the better class of the population.

Although now regarded as infectious, and propagated mainly by human intercourse, it was at first supposed that influenza was spread chiefly by an air-borne miasm, and not by personal infection or fomites in the ordinary way. The facts relied upon were the rapidity of spread of the epidemic, and the supposed simultaneity of outbreak upon large numbers of people. But it is now recognized that the rapidity of spread is not greater than that of human intercourse with modern facilities of travel, and that scattered cases usually precede the general onset of the epidemic upon a community. The epidemic, moreover, has often been observed to travel in directions opposed to the prevailing winds, and to be independent of any particular kind of weather. There can be no doubt that those engaged in outdoor occupations are often first attacked, but such people—especially postmen and policemen—may be exposed to contagion before the rest of the population. Equine influenza occasionally precedes the human disease in its epidemic form, but it is doubtful if the maladies as seen in animals and men are really identical, *i.e.*, dependent upon a common cause.

The chief arguments in favour of personal communicability are:—(1) The very frequent occurrence of cases in succession in the same household. (2) In many instances the first case in

a household or neighbourhood can be traced to exposure to infection from a previous case, or to a visit to an infected locality. (3) The special incidence of the disease upon persons liable to come into contact with infection—*e.g.*, medical men and nurses. (4) Persons living under circumstances in which the possibility of infection can be excluded (prisoners in gaols, sailors at sea, lighthouse keepers) have escaped influenza altogether. (5) That, as a general rule, in each country it has appeared first in the capital or ports of entry, and the towns have been infected earlier than country places. (6) That neighbouring communities have in certain instances been affected at considerably different dates.

The sudden, almost simultaneous, attacks of large numbers of people, following upon the appearance of a few scattered cases, is accounted for by the very general susceptibility to the disease, and its short incubation period.

It seems probable that the spread of influenza is to a considerable but unknown extent dependent upon mild, unrecognized (missed) cases and carriers—even perhaps to a greater extent than in any other of the acute infectious fevers. It seems probable that, during an epidemic, the influenza bacillus becomes widely distributed throughout the population in urban areas; and, as many of those invaded are resistant or only develop slight symptoms of illness, and are able to go about their usual occupations, the wide dissemination of the infection is very quickly brought about. Possibly 20 per cent. or more of the population during epidemics may be carrying influenza bacilli.

The most recent pandemics of influenza have been in the years 1847, 1889-92, and 1918-19. Between 1892 and 1918 influenza in this country maintained its position as a factor of importance in causing mortality, and outbreaks of some magnitude occurred in 1895, 1900, 1908, and 1915. The pandemic of 1918-19 surpassed anything previously experienced. Throughout the world it destroyed more lives than did the Great War in five years. In England and Wales alone 150,000 persons succumbed, the death-rate for 1918 being 3·13 per 1,000, and for 1919 1·17 per 1,000 from this disease alone. In this country the pandemic appeared in three waves; the first, in June and July, 1918, was short and sharp, the disease presenting the "three-day fever type," and the mortality was low, owing to a general absence of severe

complications. The disease was especially prevalent amongst young adults, the very young and the old escaping infection to a considerable extent, in remarkable contrast to the pandemic of 1890-92, and subsequent outbreaks, when the extremes of life were most affected and suffered the greatest mortality.

The second or great wave occurred in October, November, and December, 1918, and caused enormous mortality. It has been computed that of every 1,000 persons attacked in this wave, 800 suffered from the three-day fever type; the remaining 200 had pulmonary complications, of whom 30 to 40 per cent. died. The pulmonary involvement was an acute infection with virulent toxæmia in severe cases, often heralded by epistaxis, early cyanosis, and delirium. Heliotrope cyanosis almost always indicated a fatal issue, the cyanosis being due to an albuminous exudate in the alveoli and interstitial tissue of the lungs. The third wave followed close upon the second wave, and reached its maximum in February, 1920, and was very destructive, but in far less degree than the second wave. The age incidence in this wave reverted somewhat to the type of the 1890-92 epidemic, there being more cases proportionally amongst the very young and the old than in either of the first two waves.

Why pandemics of influenza occur two or three times in a century is unknown. It has been suggested that the recent pandemic was due to the war conditions prevailing in 1918; but the pandemic occurred in non-belligerent countries as well as in belligerent, where there were few or no war privations, no war strain or exposure, or alterations in social conditions arising out of war industries. There is more evidence that influenza pandemics are preceded by what may be called an alteration of "epidemic constitution" of the country or countries affected, as shown by the prevalence of diseases such as poliomyelitis, cerebro-spinal fever, encephalitis lethargica, infectious pneumonia, pseudo-influenza, etc., but why such diseases should arise or how they lead up to pandemics of influenza is quite undetermined at present.

One attack of influenza confers but slight immunity as a rule, and the immunity so acquired is probably lost in a few months, so that any general adoption of prophylactic inoculation is of but little service unless an epidemic outbreak is in sight, or at least confidently expected within a very short period

Sir Frederick Andrewes, in his Report on the Bacteriology of Influenza for the Ministry of Health Report on the Pandemic of Influenza, 1918-19, summarizes the evidence as to causative organisms as follows: (1) The position of Pfeiffer's bacillus (described as the cause of influenza in 1892) as the primary cause of the disease has been in no way strengthened. Although the predominant organism in a large number of cases, especially in the autumn epidemic of 1918, it was not invariably present. Its case remains unproven, and the crucial tests to which it has been submitted seem to indicate it rather as a secondary infection of the highest importance and significance than as the primary *materies morbi*. At the same time it cannot be asserted that, as a primary cause, it is wholly out of court. (2) The evidence for a filter-passing virus as the primary cause of the disease is suggestive, but at present a final verdict cannot be given. (3) The complications to which the epidemic has owed its abnormal fatality have been due to secondary infections, in which Pfeiffer's bacillus and the hæmolytic streptococcus have played a predominant part. The virulent types of these two organisms which prevailed during the epidemic were highly toxic, leading to the escape of blood from the smaller vessels in the lungs and bronchi, setting up the especially fatal forms of pneumonia, with the accompanying heliotrope cyanosis, that characterized the epidemics of the end of 1918 and commencement of 1919.

The use of prophylactic vaccines during the pandemic to avert attack and lessen the severity of complications was extensively tried.

The prophylactic vaccine used in the Army Medical Service during the pandemic period, 1918-19, was constituted as follows:

	First Dose.	Second Dose.
B. influenzæ	30 millions	60 millions.
Pneumococcus	100 ,,	200 ,,
Streptococcus	40 ,,	80 ,,

A number of different strains and types of each organism were utilized, the organisms having been recently isolated from cases of the disease. The vaccine was sterilized at 55° C. for thirty minutes, 0·5 per cent. of carbolic acid being then added. Whenever possible, two doses of the vaccine were given at an interval of ten days.

The results obtained with the army vaccine when used as a

prophylactic in various camps in England during the pandemic period are given as follows:

	Strength.	Incidence of Attack.	Incidence of Pulmonary Complications.	Incidence of Deaths.
Inoculated ..	15,624	14·1	1·6	0·12
Non-inoculated ..	43,520	47·3	13·3	2·25
		Ratios per 1,000.		

The vaccine prepared for the Ministry of Health differed from the above in containing 200 million *B. influenzæ*, 100 million pneumococci, and 30 million streptococci for the first injection, and double these quantities for the second injection. The St. Mary's Hospital vaccine is much stronger—namely, *B. influenzæ* 500 millions, pneumococci of mixed types 1,000 millions, streptococci 100 millions in 1 c.c.

As regards prevention, theoretically, notification of cases, isolation of the sick, disinfection of premises, and disinfection of the excretions, especially of the sputum and of soiled linen, should be, as for other infectious diseases, the proper means of checking or stamping out an epidemic. But such measures are really impracticable for general adoption, owing (1) to the difficulty of making an exact diagnosis in the early stages of an epidemic, or of mild cases at any time; (2) to the wide and rapid diffusion of the infection, and to the fact that the wage-earning periods of life are most affected (the movements of adults being far more difficult to control than those of children); and (3) to the impossibility under the circumstances of treating influenza as a dangerous infectious disease, and inflicting a penalty upon those found exposing themselves in public places. An effort, however, should always be made to promptly isolate the first case occurring in a house or institution and to carefully disinfect the sputum; and while the disease is prevalent it is well to avoid exposure to cold and fatigue, to clothe the body warmly, to avoid indulgence in excess of alcohol, and not to visit places to which large numbers of the public resort.

During pandemic prevalences, such as that of the autumn of 1918, the enormous number of cases arising practically simultaneously renders unavailing any systematic efforts in the way of medical relief or nursing. Large numbers of cases can get no

medical attention, no nursing, and even in the event of death no burial for many days after death has occurred. In the lesser epidemic outbursts the organization of medical attendance and nursing is attended with good results, the latter especially tending to reduce the mortality from lung complications. Nurses run considerable risk of contracting the disease, and are advised to wear face masks when in close attendance upon patients, and to use disinfectant solutions for the thorough irrigation of mouth, nose, and throat.

As influenzal pneumonia is now a compulsorily notifiable infectious disease, local authorities are empowered to expend money in providing medical and nursing attention for the sick where needed, and also in enlightening the public by means of leaflets, posters, and lectures as to the necessary precautions that should be taken to protect themselves from infection, and of the measures required in the event of attack to ward off complications and prevent the spread of the disease to others.

Contagious Ophthalmia.

There are two kinds of contagious eye disease: the grey granulation (trachoma) and purulent conjunctivitis; the former appearing to predispose the sufferer to take the latter. These diseases are not uncommon in industrial schools and barracks which are badly ventilated, and where the inmates are not supplied with separate basins and towels for ablution. They are chiefly transmitted from the sick by inoculation of the eyes of the healthy with the secretions and discharges left on bed linen and towels; but it is also probable that the contagion is carried through the air in dried epithelial or pus cells.

In all forms of purulent ophthalmia a pyogenic micro-organism —the *Staphylococcus pyogenes aureus* or *albus*—is usually the active cause of the disease.

The ophthalmia caused by gonorrhœal infection (gonococci) of the eyes, and the ophthalmia neonatorum inoculated from purulent vaginal discharge, are especially virulent and destructive forms of eye disease. *Ophthalmia neonatorum* is productive of about one-fourth of all cases of blindness, and of at least one-third of the blindness in inmates of British blind schools. One of the rules issued by the Central Midwives Board is to the effect that, "As soon as the child's head is born, and, if possible, before the eyes are opened, its eyelids should be carefully cleansed" with

clean, lukewarm water. Moreover, whenever there is inflammation of the eyes, however slight, medical help must be sought. It is a growing practice to apply 1 or 2 drops of 1 per cent. solution of nitrate of silver to the eyes of infants at birth as a precautionary measure.

Ophthalmia neonatorum was made compulsorily notifiable in England and Wales in 1914. Medical practitioners and certified midwives are required to notify cases to the Medical Officer of Health. What has to be notified is "a purulent discharge from the eyes of an infant commencing within twenty-one days from the date of its birth."

Cerebro-Spinal Fever, or Epidemic Cerebro-Spinal Meningitis.

This is a specific disease due to a micro-organism having a diplococcus form, often called the meningococcus (*Diplococcus meningitidis intracellularis* of Weichselbaum), which is found in the cerebro-spinal fluid in the polymorphonuclear cells, which are very abundantly present, causing the fluid to be turbid. The meningococcus is said to be constantly present in the naso-pharynx of the sufferers, and not infrequently in the throats and noses of those in attendance upon the sick. Of 445 persons bacteriologically examined in London in the early months of 1915, when the disease was prevalent, who had been in close or repeated contact with a patient, 11 per cent. were found to be harbouring meningococci in the naso-pharynx. Of non-contacts during the same period, from 10 to 13 per cent. were found to be carriers. It seems probable that, during epidemic prevalences of cerebro-spinal meningitis, carriers may exceed the above figures, but only very exceptionally do they themselves develop the disease.

The disease is undoubtedly spread by means of carriers and of mild, unrecognized, or abortive cases, of which there are probably much larger numbers than of cases with definite meningeal symptoms. The number of carriers must be much larger than the number of mild cases, and the disease is more often communicated by carriers than in any other way. It would appear that the proportion of persons in any population who offer so little resistance to the meningococci as to develop meningeal symptoms on invasion is a very small one, as compared with those who remain unaffected or develop only a minor illness. (For treatment of carriers, see p. 433.)

The disease is not spread as a meningitis. What is spread is the meningococcus present in the secretions of the nose and throat. Meningitis may arise if the meningococci find their way through the blood or lymph streams to the meninges of the brain and spinal cord. In some rapid or fulminant cases an acute septicæmia occurs, which rapidly ends fatally before the meninges are seriously affected. It is especially in these cases that the characteristic "spotted fever" rash may be present. In other cases there are definite symptoms of illness, but the meninges are unaffected or only slightly affected, and recovery from these less serious conditions is usual. A diagnosis, however, of these slighter cases can hardly be made unless the meningococcus is isolated from the naso-pharynx.

The infectivity or otherwise of contacts can be determined by taking swabs from the *upper part of the naso-pharynx*; swabs from the fauces are of little value. To avoid contamination of the swab by bacteria of the mouth and fauces the swab should be mounted on a long rod, curved at its distal end, and protected by a metal canula. The swab should not be extruded until the end of the canula has passed behind the uvula, and should be withdrawn into the canula immediately after contact has been made with the naso-pharyngeal membrane. As the meningococci very quickly perish when withdrawn from the throat, the Petri dishes should be at hand for immediate inoculation, and forwarded to the laboratory without delay.

The nasal discharge is sometimes so profuse during a recognized attack as to cause the disease to be mistaken for influenza. It is probably the main channel of infection from the sick, but the infectivity of many cases appears to be exceedingly slight, as multiple cases in a family or house are uncommon, and contacts are only very occasionally attacked. Since, however, direct personal infection probably plays some part in the spread of the disease, it is well to endeavour to isolate the sick, and to apply suitable measures of disinfection. Overcrowding and insufficient ventilation appear to predispose to attack, but the sanitary environment is not a dominating factor in etiology.

The disease is often preceded by catarrhal or influenzal attacks, and it is possible that the strain of meningococcus present in the naso-pharynx is rendered more virulent by association with influenza bacilli, or with virulent forms of pneumococci and streptococci causing nasal and tonsillar catarrhs.

One cannot but be struck by the suggestive coincidence of the high sick-rate from catarrhal affections with the prevalence of cerebro-spinal fever cases. It is probable that catarrhal affections predispose to meningococcic infection and also favour its spread, and that "catarrh" and "influenza" are often abortive cases of cerebro-spinal fever. At the end of 1914 and in the early months of 1915 catarrhal affections were numerous, and their prevalence roughly coincided with the outbreak of cerebro-spinal fever.

In its sporadic form the disease is often diagnosed as posterior basic meningitis, the specific organism being either the meningococcus or a closely allied form. Cerebro-spinal meningitis is not an infrequent complication of many febrile diseases, but this form is never epidemic or communicable; nor is it attended by the petechial eruptions occasionally characteristic of true cerebro-spinal meningitis. Anomalous forms of the disease have been mistaken for influenza, enteric fever, and other diseases.

The disease is endemic in many large towns in this country, on the Continent, and in America. It was relatively rare in this country until 1915, when a considerable epidemic spread throughout many parts, arising probably in the first instance amongst the troops in encampments and billets, and thence spreading to the general population. The conditions of housing of the troops in the autumn of 1914 were in many places unsatisfactory, especially as to overcrowding and ventilation. Moreover, many of the new recruits were undergoing severe training to which they were unaccustomed, thus inducing a condition of physical exhaustion which may predispose to attack. The disease is generally more prevalent in the late winter and spring than in the summer and autumn.

The case mortality is generally high. In the County of London in 1915, 712 cases of the disease were notified with 241 deaths, the case mortality being 34 per cent. About 60 per cent. of the cases were under fifteen years of age. Under one year of age and over forty-five years of age the case mortality was 50 per cent. or more. The disease was widely distributed throughout the County of London, although, having regard to the population, the number of cases notified was relatively small.

The diagnosis of a case with meningeal symptoms can be confirmed bacteriologically by a lumbar puncture of the cerebro-

spinal canal, the meningococcus being searched for in the cerebro-spinal fluid so obtained, and appropriate tests applied to the organism when isolated. Lumbar puncture, with the removal of about 30 c.c. of fluid, is also a palliative for the relief of symptoms, owing to the escape of fluid under abnormal pressure in the cerebro-spinal canal. Anti-meningococcus serum (obtained from horses immunized for many months with strains of meningococci obtained from human sources), introduced with a syringe into the spinal canal at the seat of puncture, is useful in many cases as a curative measure, though it fails in some.

The disease is now compulsorily notifiable by order of the Local Government Board. Cases amongst the poorer classes should be removed to hospital, as hospital treatment is very desirable for so serious a disease.

Lieut.-Col. Gordon has found that the meningococci present in the cerebro-spinal fluid of cases of cerebro-spinal fever occurring among troops are not strictly uniform in all cases. Although alike in morphological, cultural, and fermentative characters, the organisms from different cases may nevertheless be distinguished by the use of serum tests into distinct types. Four main types have been described, of which two have been especially prominent and abundant in 1915-16. These types appear to breed true, and apparently only a single type is present in the cerebro-spinal fluid of any one case; and it is always the same type which is present, if at all, in the posterior nares of the same patient. If the contacts of a case of the disease have the organism in their nasal passages, it is normally of the same type as that of the case of disease. As regards preventive measures, therefore, it would appear to be necessary only to isolate in quarantine persons found to carry the types associated with the prevalent epidemic, whilst those harbouring meningococci not of the special type may be disregarded. In treatment curative sera should be prepared and administered homologous with the type or types actually prevailing in any epidemic outburst; and for purposes of diagnosis standard sera and cultures of different types should be in readiness (Second Annual Report of Medical Research Committee, National Health Insurance, 1915-16).

As regards preventive measures, where possible, carriers should be segregated, and not released until at least two negative swabbings of the posterior naso-pharynx have been obtained. If available, carriers should inhale chloramine-T

in an inhalatorium, or disinfectant solutions should be passed through the nose to return by the mouth, but the evidence as to the value of such methods is conflicting. Spraying and gargling are of little value. Spit-cups should be provided for the sick, and great care taken with handkerchiefs and linen. Carriers should be lodged in very well ventilated rooms kept at a comparatively low temperature, as the meningococci apart from the body die rapidly in cold air. The duration of the infectivity of contacts is unknown. Carriers should be instructed to spend as much time as possible in the open air, and to avoid crowded rooms, theatres, and cinema halls. Kissing, close contact, etc., between the sick or carriers and healthy persons should be absolutely prohibited.

In the British Army, when three or more cases of cerebro-spinal meningitis have occurred within a few days of each other in the same station, a representative sample (50 to 100) of the men who have *not* been in contact with a case are examined by the bacteriologist. If this examination indicates that there is a high percentage (20 per cent.) of carriers among the general military population, an attempt is made to reduce their numbers by abating any overcrowding, improving the ventilation in the barrack rooms, and especially by increasing the 3-foot linear space between the beds which is the normal allotment. As many men as possible are then passed through an inhaling chamber (ten minutes for each man), the air of which is kept charged by means of a steam atomizer with 2 per cent. solution of zinc sulphate. This is continued until it is found that there is no further reduction in the local carrier rate. If the bacteriological examination shows that infection is being introduced by recruits, they should be passed through the inhaling chamber for a week, commencing on the day they join the depot. As soon as a case of cerebro-spinal meningitis is diagnosed, the patient is removed to an isolation hospital, and his clothing, bedding, feeding utensils, and quarters disinfected. The immediate contacts of the patient —*i.e.*, those who have slept in the same room, hut, or tent with him, or have sat near or opposite to him at meals—are segregated in roomy, freely ventilated quarters. After bacteriological throat swabs have been taken, these contacts are treated with nasal insufflations and gargles of an antiseptic solution containing 1 part of permanganate of potash in 5,000 parts of 0·8 per cent. solution of sodium chloride. The men found to be carriers are

segregated until two successive swabs taken at intervals of several days are returned as negative. A small residuum are found to be chronic carriers. Such men are allowed to return to duty after special consideration, but are kept under observation and periodic bacteriological examination.

Acute Poliomyelitis (*Infantile Paralysis*).

This disease is due to a minute micro-organism which is filterable through porcelain. It has been isolated in artificial cultures, and is visible under the higher powers of the microscope. It probably enters the body through the naso-pharyngeal mucous membrane, and causes acute localized inflammation in the anterior cornua of the grey matter of the spinal cord, resulting in degeneration of the large motor cells of the cornua, thus giving rise to partial or complete paralysis of various groups of muscles (arms and legs). Polio-encephalitis is a comparatively rare form of the disease in which the brain is primarily or secondarily affected. The disease occurs sporadically and in epidemic form, the latter being commonest in summer and autumn. In London, where the disease has been compulsorily notifiable since 1911, there has been a regular prevalence curve. In the first two quarters of the year the number of cases is small, a well-marked rise occurs in July, a maximum being reached in August or September, and a decline takes place through the autumn. The prevalence is very much the reverse of cerebro-spinal meningitis, which has the greatest prevalence in the winter and spring (first two quarters). In New York in the autumn of 1916 the disease assumed the character of an epidemic, and caused a heavy death toll, the case mortality being about 25 per cent. Exceptional measures of isolation and quarantine were found necessary for its control. A majority of the cases occur in children under six years of age. The fatality varies in different epidemics from 6 to 30 per cent.

The incubation period is somewhat uncertain, but is often between one and four days. The disease has been produced experimentally in monkeys by inoculating them with an emulsion from the nasal mucous membrane or the submaxillary lymphatic glands of a human case, and by inhalation of the virus, or by painting it on the nasal mucous membrane. It seems probable, therefore, that the disease is transmitted in man from person to person by direct contact, in the same way as diphtheria and

cerebro-spinal meningitis. Transmission undoubtedly occurs through healthy "carriers" and abortive cases without characteristic paralyses or severe illness; such abortive cases formed 15 per cent. of the total cases in the Swedish epidemic. These carriers and abortive cases probably are much more instrumental in spreading infection than the serious acute cases with recognizable paralysis.

The infective power and virulence of the specific micro-organism show considerable variations in different outbreaks. The virus as ordinarily present in human beings, even during severe epidemics, has a low infective power for monkeys. But by passage from monkey to monkey, it tends to acquire a very much higher activity or potency.

Multiple cases rarely occur in houses, and many apparently susceptible children escape infection. Epidemics more often occur in small towns and in rural communities than in the larger cities, and there seems to be no relationship between the disease and the more common insanitary conditions of dwelling-houses. It has been thought that the presence of much dust in the air, raised from roadways by motor traffic, may have some effect in propagating the disease, and flies may possibly play some part in transmission. In the United States the biting stable-fly—*Stomoxys calcitrans*—is regarded as a possible agent in the spread of infection, but the evidence of such a mode of transmission is very inconclusive. Moreover, the virus has never been detected in human blood.

There appears to be considerable variability both in the infectivity and the virulence of the causative agent, as not only do many apparently susceptible persons, who are exposed to infection, escape, but when illness does result, it exhibits such varying types of severity. Thus, cases occur (1) resulting in extensive and lasting paralysis of groups of muscles; (2) in permanent slight paralysis; (3) in transient paralysis ending in complete recovery; (4) cases without definite paralysis, but only muscular weakness of short duration.

In poliomyelitis the cerebro-spinal fluid is clear, but lymphocytes are present, and no micro-organism is discoverable.

As regards preventive measures, poliomyelitis is now a compulsorily notifiable disease, by order of the Local Government Board. Cases of the disease should be isolated as far as possible, and amongst the working classes are best removed to hospital.

The virus leaves the infected body in the secretions of the nose, throat, and intestines, and it is present in the secretions of the nose and throat of carriers.

As the virus is thrown off from the body mingled with the secretion, it withstands for a long time even the highest summer temperatures and complete drying. Thus infection may be conveyed by dust arising from the dried secretions. The virus may live for a long time in the throat, sometimes for months.

As with cerebro-spinal meningitis, the number of mild and abortive cases and of carriers of the infection may be much larger in infantile paralysis than the number of the victims of an epidemic of that disease.

Discharges and soiled articles from patients should be disinfected. To prevent the spread of the disease by healthy contacts or by suspects, the throats and nasal passages of such persons should be sprayed with 1 per cent. solution of peroxide of hydrogen, or 1 in 500 permanganate of potassium solution. Children from infected homes should be excluded from school.

Encephalitis Lethargica.

This is a general infectious disease characterized by certain manifestations originating in the central nervous system, of which the most frequent and characteristic are progressive lethargy or stupor, and a lesion in or about the nuclei of the third pair of cranial nerves. During March and April, 1918, a number of cases of an obscure disease were reported in England. The disease was first regarded as "botulism," and later as the cerebral form of acute poliomyelitis, but further investigation established encephalitis lethargica as a distinct disease or clinical entity. The disease is now generally recognized, and during the last two years its occurrence has been world-wide. In London, in 1920, 134 cases were notified; in 1921, 240 cases; and in 1922, 71 cases.

In 1919 McIntosh, by using a filtered emulsion of cerebral tissue obtained from a fatal case of encephalitis lethargica, succeeded in transmitting the disease to a monkey, and from this monkey, in series, to other monkeys and rabbits, thus showing that the disease is caused by a living virus. This virus is filterable, and enters presumably through the naso-pharynx, thence attacking the brain in the region of the nuclei of the third nerve, but other portions of the central nervous system may be affected.

At post-mortem examinations no conspicuous macroscopic lesions are found, and the meninges are only slightly affected. In the spinal cord the lesions are slight or absent, and no characteristic changes have been observed in the cerebro-spinal fluid.

Clinically three types are distinguishable: (1) General disturbance of the functions of the central nervous system, but without localization; (2) various localizations in the central nervous system; (3) mild or abortive cases. The case mortality of definitely recognized cases is a high one—namely, from 20 to as much as 50 per cent.—but would be much lower if the mild or abortive cases, which are seldom recognized, were included. Recovery is often tedious, and complicated by numerous nervous sequelæ.

No specific treatment is as yet available. Most cases require very careful nursing, and for this reason are best treated in hospitals. The disease being compulsorily notifiable, the removal to an isolation hospital is usually feasible. The degree of infectivity from person to person is of a low order, and the great majority of cases notified are sporadic, and apparently unconnected with any previous case; but multiple cases occur occasionally in the same household, as well as in institutions, a notable institutional outbreak being one reported by Dr. Macnalty at Derby in August, 1919, where in a home for girls twelve females were attacked out of twenty-two resident in the home between the 14th and 27th of the month.

In encephalitis lethargica, as also in cerebro-spinal fever and acute poliomyelitis, it would appear that the pathological agent or living virus is much more frequently present in the human organism than the clinical symptoms indicate; consequently, carriers are likely to be numerous, some of these presenting symptoms of naso-pharyngeal catarrh, or nervous symptoms, such as headache, slight lethargy or apathy, and transient facial paralyses, whilst others possibly are in a normal state of health. An attack of the disease in recognizable form is the result of loss of immunity on the part of a carrier to the effects of the virus he is harbouring, or to a non-immune person becoming infected with a virus of definite pathogenic strain. A relationship has been suggested between encephalitis lethargica and epidemic influenza, but has not been satisfactorily established.

In investigating a case or an outbreak the Medical Officer of Health should make particular inquiry as to any possible asso-

ciation with a carrier or a mild or abortive case, and he is required to fill up a special inquiry form for transmission to the Ministry of Health. Although the risk of infection is slight, cases treated at home should be isolated as far as possible, and those in contact with a case are advised to use antiseptic nasal and throat sprays and douches.

Happ and Mason have directed attention to a number of instances of continuous hiccup which were observed during the Canadian epidemic of encephalitis, and note that, while the relationship of the hiccup symptom to encephalitis is still obscure, an epidemic in which that was the only symptom recently occurred in the eastern part of the United States and another in Austria. Walshe agrees with the French clinicians in believing that these cases belong ot the epidemic encephalitis group.

Pneumonia.

That pneumonia may occur in epidemics, or even pandemics, has been recognized for many years. The mortality of several outbreaks in this country has attained the proportion of 5 per 1,000 living of the community. So far as has been ascertained, neither meteorological nor insanitary conditions appear to exercise any marked influence on the epidemic prevalence of pneumonia, but non-epidemic pneumonia is markedly a disease of the colder months, and is especially associated as a complication with influenza and measles.

The primary lobar pneumonia of adults and primary lobular pneumonia of children are more often due to the pneumococcus of Fraenkel than to any other organism. Secondary bronchopneumonias are caused by various organisms, such as pneumococci, hæmolytic streptococci, staphylococci, either singly or in association. Pneumococci of non-virulent or but slightly virulent strain are normally present in the saliva of many healthy people, often estimated as from 20 to 50 per cent. of the population. They are more often present in the cold months of the year than in the warm, and in the former months the percentage of virulent strains is highest—80 per cent. They are apt to persist in the lung secretions for long periods after convalescence from attacks of pneumonia. It is evident that the resisting power of most people is sufficient to prevent invasion of the body by the pneumococcus, but the bodily resistance is lessened by cold, fatigue, and other debilitating causes.

Pneumococci have been found in the dust of rooms occupied by patients. They do not survive for long drying and exposure to sunlight. As some cases of primary and secondary pneumonia appear to have a distinct infective quality, isolation of cases in separate rooms or wards of hospitals is desirable, and there should be abundance of fresh air and daylight. Acute primary pneumonia and acute influenzal pneumonia are now compulsorily notifiable diseases. There is a considerable body of evidence that the injection of vaccines containing mixed pneumococci, Pfeiffer's *Bacillus influenzæ*, streptococci of hæmolytic type, and *Micrococcus catarrhalis* confers temporary immunity from primary and secondary pneumonias.

Puerperal Fever.

"Puerperal fever" is generally caused by the introduction of infection into the genital tract from without the body, and usually by the neglect of aseptic precautions as regards the hands and obstetric instruments, during and immediately after childbirth. The term "puerperal fever" has been abandoned by the Royal College of Physicians of London, and "septicæmia, pyæmia, septic peritonitis, septic metritis, and other acute septic inflammations in the pelvis, occurring as the direct result of childbirth," are now described as "puerperal pyæmia," "puerperal septicæmia," or "puerperal septic intoxication." The Registrar-General still classes a few deaths under "puerperal fever."

In the four years 1911-14, in England and Wales, the deaths assigned to complications of pregnancy and childbirth corresponded to an average rate of 4 per 1,000 births. Of this number, over one-third were caused by puerperal fever. The textile towns stand pre-eminent in the toll of life exacted from mothers in child-bearing. Unsatisfactory midwifery, factory work for women, and possibly the use of abortifacients all play their part in producing high mortality rates in childbirth in these districts. During the four years 1911-14 the average case mortality of notified cases of puerperal fever in England and Wales was 58 per cent.; for the year 1920 it was 59 per cent. Whilst puerperal fever has almost completely disappeared from lying-in hospitals in this country, outside such hospitals the disease still continues, and is most prevalent where midwifery practice is the least satisfactory.

Various micro-organisms have been found associated with the disease, *e.g.*, *Streptococcus pyogenes*, *Staphylococcus aureus*, the *Gonococcus*, and *Bacillus coli communis*.

Insanitary conditions, more especially the fouling of air by overcrowding and drainage defects, probably play some part in determining the occurrence of the disease.

To prevent the spread of "puerperal fever," the midwife or lying-in attendant should cease attendance on other lying-in women until thorough disinfection has been accomplished. This should include a hot bath for the person, with the use of soap and disinfectants, thorough cleansing with soap and disinfectants of the hair, hands, and finger-nails; steam disinfection of all personal clothing; and sterilizing in boiling water of all midwifery instruments, catheters, and douches. The obstetric bag should be sprayed inside and out with a disinfectant spray, and a clean lining and pockets substituted for the old ones.

Cancer.

Cancer now contributes 1 to every 12 deaths registered in England and Wales, and is even more destructive to life than the other great scourge—tuberculosis.

The causes determining the prevalence of this disease are still wrapped in obscurity, and the view that cancer is due to a parasite, which possesses some degree of infectiveness, is no longer regarded as tenable. Certain investigations seemed to indicate that cancer, like enteric fever, has an endemic prevalence, and that it affects in a higher degree populations living in low-lying river valleys with clay soils than those on high, dry, and non-retentive soils. Such endemic areas might be close to others on which the disease rarely occurred; and isolated "cancer houses," or groups of such houses, in which successive families have suffered from cancer, though in no way related to each other, were held by many to exist in certain districts; but the evidence both as to endemic areas and cancer houses is weak.

There are probably no true "cancer houses" or "cancer villages." The circumstance that the disease has been unusually prevalent in a house or village is sufficiently explained by coincidence or the exceptionally favourable ages of the dwellers. A village from which the younger people have gone to obtain

work elsewhere would naturally furnish a larger number of cases of cancer than another village of equal population with the usual proportion of young people.

With reference to "cancer houses" it must be borne in mind that the chance that a man over thirty-five will die of cancer is at present about 1 in 9·7, and for a woman about the same age it is about 1 in 7·4; it is hardly surprising, therefore, that as a chance coincidence a cancer history should attach to particular houses.

All races of mankind are liable to cancer, and likewise all vertebrate animals—with the possible exception of reptiles—whether they be living in a state of nature or in captivity. The histological lesions characteristic of the disease throughout the vertebrates are identical with those found in man. Cancer in the lower animals has the same higher incidence in old age, and therefore the same relation to the duration of life as in man. Cancer has been successfully inoculated from mouse to mouse, the new tumour being of exactly the same nature as the original one. A mouse cancer will only grow in other mice of the same race; that is to say, a wild mouse cannot be inoculated with tame mouse cancer, and vice versa. Propagation succeeds as well, and perhaps better, in young mice as in old ones. The cancer cells transmitted experimentally from one mouse to another continue to grow and divide in the inoculated mouse. The tissues of the new host do not acquire any cancerous properties; they merely react to the presence of the cancer-cells, and supply them with nourishment. The process is fundamentally different from all known processes of infection (Bashford).

The death-rate per million living from cancer varies considerably in different parts of England and Wales.

During the fifty years ending 1910 there has been an increased mortality registered from the disease in England and Wales, as the following table serves to show:—

Deaths per 1,000,000 Living at all Ages.

	1851–60.	1861–70.	1871–80.	1881–90.	1891–1900.	1901–1910.
Males ..	195	242	312	430	598	771
Females ..	434	510	617	739	903	1,025

The death-rates from cancer in England and Wales during recent years have been as follows:—

ENGLAND AND WALES.

Year.	Rate per thousand of population.	Year.	Rate per thousand of population.
1911	0·992	1916	1·166
1912	1·023	1917	1·210
1913	1·064	1918	1·218
1914	1·069	1919	1·145
1915	1·121	1920	1·161

This increase, which is world-wide, is probably not altogether real, but is to some extent due to better diagnosis and certification of causes of death. "The cancerous affections of males are in much larger proportion internal or inaccessible than are those of females, and consequently are more difficult of recognition; so that any improvement in medical diagnosis would add more to the male than to the female figures" (Ogle). It is a significant fact, therefore, that among males aged thirty-five to forty-five the rate of increase has been 89 per cent., while among females of the same age it has not exceeded 37 per cent. Moreover, in Frankfort-on-Main, the deaths are classified into those from cancer of inaccessible and of accessible regions, and the increase of cancer is confined to the former. The greater number of survivals of late years to the higher ages will also account for a slight increase in the incidence of a disease of a degenerative type such as cancer. But despite these facts some of the increase appears to be real, and in this increase there is a marked predominance of cancer of the digestive organs.

As compared with twenty years ago, cancer of the stomach, intestines, rectum, and liver has shown a notable increase in both sexes, whilst cancer of the tongue, œsophagus, and bladder has shown a marked increase in males only. For females there has been a considerable increase in cancer of the breast, but there has actually been a decrease in cancer of the uterus and ovary. The fact that the increased mortality of both sexes from cancer is especially marked at ages subsequent to forty-five years of age in females, and thirty-five years in males, and that the increased mortality rises in both sexes with an advance in age, is suggestive of the larger proportion of old people in the community at the present time, owing to the lowered general death-rate, and the consequent saving of life in the earlier age-periods. But some

of the increase of mortality in the later periods of life may be due to improved operative procedures in surgery, lives being prolonged by operation, but eventually dying of a recurrence of the growth, which it was not in the power of the surgeon wholly to eliminate.

The recorded increase in the mortality rate is largely a reflection of improving diagnosis; but there is probably some truth in the general opinion that the incidence of cancer has increased. Certainly cancer of certain parts of the body (notably the tongue) has increased of recent years. Since 1911 the national records in the Registrar-General's office admit of being classified into the parts of the body affected, and this circumstance will permit of a better study of the incidence of the disease. As to the cause of the disease, our present knowledge admits of little more than the statement that local irritation and the abuse of alcohol appear to predispose to it. The effect of local irritation is evidenced by the exceptionally heavy incidence of the disease upon chimney-sweepers, the smokers of clay pipes, and the women in India who chew the betel nut. Tar and pitch cancer, X-ray cancer, are further instances; and cancer has been experimentally produced in mice, etc., by such irritants as tar, paraffin oils, arsenic, and soot extract. The consumption of very hot rice by men in China is also said to favour the prevalence of cancer among them.

Certain predisposing factors in the causation of cancer are now pretty generally accepted. Some of these are beyond individual control; others, however, such as occupation and habits of life (determining a localized chronic irritation or inflammation), and suspicious growths in connection with old scars and simple tumours, call for more general recognition among the public, in order that preventive measures and early treatment may be put in operation.

It has been demonstrated that the blood in cancer cases contains antibodies and antiferments opposed to the cancer cell; this is shown by the presence in such cases of special reactions.

The American Society for the Control of Cancer has published the following statement on cancer for the enlightenment of the American public, and to induce an early resort to medical advice and treatment:—

1. Cancer begins as a small local growth which can often be safely and easily removed in the early stages by competent surgical

treatment, or in certain favourable cases by radium, X ray, or other methods.

2. The beginning of cancer is usually painless; for this reason its onset is doubly insidious, and other danger signals must be looked for and heeded in time.

3. Cancer is not a constitutional or blood disease, and there should be no thought of disgrace or hereditary taint associated with it.

4. Cancer is not a contagious disease, and there is no danger from living in the same house or from contact with a patient.

5. In an ordinary sense, cancer is not inherited. Some authorities believe that there may be inheritance of a certain tendency to the disease, but even this is not clearly established. The disease is so frequent that, by the very law of chance, many cases will occur in some families. Life insurance companies do not regard cancer in the family as a reason for rejecting applicants or increasing premiums.

6. A persistent lump in the breast, or continued abnormal discharge or bleeding, should take a woman to her doctor forthwith. The increased flowing which frequently occurs at the change of life is always suspicious, as is the return of flowing after it has stopped.

7. Sores, cracks, lacerations, lumps, and ulcers which do not heal, warts, moles, or birth-marks which change colour or appearance, are danger signs which demand competent medical investigation and treatment.

8. Persistent indigestion in middle life, with loss of weight and change of colour, may mean internal cancer.

Rheumatic Fever.

It is now recognized that this disease is a specific disease, and quite distinct as to its origin from ordinary rheumatism. The facts supporting this view are:—(1) Excessive, or even epidemic, prevalence tends to manifest itself at irregular intervals of from three to six years. Longstaff has shown the very striking analogy that exists between the mortality curves in this country of rheumatic fever, erysipelas, and puerperal fever both when plotted out as annual death-rates for a period of years, and also when drawn to represent the average weekly deaths of a series of twenty years. The annual curves and the seasonal curves of all three diseases rise and fall together in a very remarkable manner,

suggesting, if not an actual community of origin, at any rate a co-relation of distinctive character. (2) Newsholme's researches have shown that there is a very definite relationship between deficient rainfall, low ground water, and high soil temperature on the one hand, and the prevalence of rheumatic fever on the other. In Norway the disease is compulsorily notifiable by medical attendants, and exceptional opportunities are thus afforded in that country of studying the epidemiology of the disease. Elsewhere, the evidence collected is generally derived from hospital returns. (3) The type of the pyrexia, and the articular and cardiac disturbances, are best explained on the microbic doctrine. (4) The marked effect of the administration of salicylates has long been claimed as proof in support of the specific nature of the disease. Several bacteriologists in this country and abroad have described a diplococcus in acute rheumatism, which they have isolated from the endocardium, pericardium, fibrous nodules, tonsils, and urine in cases of the disease. When inoculated into animals (rabbits), the latter die with arthritic and cardiac lesions from which the diplococcus has again been isolated.

Venereal Disease.

Syphilis.—The causative organism of this disease is the *Spirochæta pallida*, an extremely minute and delicate, spirally twisted, thread-like organism, which is actively motile, the character of the movements being a rapid rotation on its long axis as well as a progressive movement (Leishman). The organism is present in the substance of, and in the discharges from, the primary sore or chancre, and can best be seen under a high power of the microscope with dark ground illumination, when the spirochæte will be observed as an actively moving, illuminated object against the dark background. By this means it is possible to make a diagnosis of syphilis on the first appearance of a venereal sore, although the failure to find *Spirochæta pallida* does not necessarily imply that the venereal sore is not specific. The spirochætes may also be found in the indurated glands, in the various secondary eruptions of syphilis, and also in the blood of syphilitic patients in certain stages of the disease. They are, however, only very rarely found in the tertiary lesions of syphilis. In congenital syphilis, on the other hand, the spirochætes may often be found in large numbers and widely distributed in the tissues.

There is good reason to believe that there is a considerable amount of syphilis in the community. In the opinion of the Royal Commission on Venereal Diseases, the number of persons who have been infected with syphilis, acquired or congenital, cannot fall below 10 per cent. of the whole population in the large cities. The percentage affected with gonorrhœa must greatly exceed this proportion. Certain common and fatal diseases, which were not formerly regarded as having any connection with syphilis, are in reality the late after-effects of syphilitic infection. Amongst these may be mentioned general paralysis, tabes dorsalis, optic atrophy, aortic sclerosis, sometimes resulting in aortic aneurysm, aortic regurgitation, and angina pectoris from involvement of the coronary arteries of the heart, and possibly congenital idiocy or imbecility as a result of congenital syphilis.

Syphilis probably is also a predisposing cause of tuberculosis and cancer of the tongue. The number of deaths primarily due to syphilis must be very large, but can never be known with any certainty, so long as the present system of death certification is in force. If death certificates were handed to the Registrars and not to relatives, and it was compulsory upon the medical certifier to state what in his opinion was the primary cause of the disease from which the patient died, data would soon accumulate which would lead to a recognition of the part played by syphilis as a cause of death and incapacity. Syphilis is also a common cause of abortions, still-births, and premature births. Many of the deaths of infants ascribed to marasmus (wasting) and atrophy are syphilitic in origin. In the case of 34 syphilitic mothers, Sir F. Mott found that 175 pregnancies resulted in only 30 apparently healthy children, leaving 104 premature births, still-births, or deaths in infancy, and 41 seriously diseased offspring.

The serum diagnosis of syphilis, which has been rendered possible by the researches especially of Wassermann, Neisser, and Bruck, is now capable of referring the later affections of syphilis to their true origin, and also enables a diagnosis to be made in cases of tertiary syphilis of uncertain nature. (For an explanation of the Wassermann reaction, see pp. 424 and 425.)

In this country an attempt was made by the Contagious Diseases Act of 1864 to limit the spread of venereal diseases in certain military and naval garrison towns. Any woman charged with being a prostitute and diseased, and plying her trade within

certain limits, could be summoned before a magistrate, who had power to order her to be taken to a certified hospital for medical examination. If found to be suffering from a contagious venereal disease, the magistrate could order her detention for treatment for a period not exceeding three months. A later Act of 1866 enabled a justice to order any woman charged with being a prostitute to submit herself to a periodical medical examination for any period not exceeding one year. These Acts continued in force until May, 1883, when an order was issued abolishing the compulsory examination of women; and they were finally repealed in 1886.

It is very doubtful if these Acts had any real effect in controlling the spread of venereal disease in English garrison towns. Only a certain proportion of the diseased prostitutes were ever brought under control in the manner indicated by the Acts; whilst those who escaped police supervision, and the men who consorted with them, were free to spread infection with impunity. Notwithstanding the absence of any C.D. Acts, the prevalence of venereal diseases in the British Army in the United Kingdom has been steadily diminishing of recent years. This fortunate result is attributable to greater temperance amongst the soldiers, a higher standard of education and intelligence, more opportunities for healthful recreation both of mind and body, and the greater interest displayed by regimental officers of all grades in the health and well-being of the men, and in keeping them fit for the duties of their calling. On the other hand, few can dispute the need for more stringent measures against brothels, soliciting, "procuring" and immoral literature; and there is much to be said in favour of raising the "age of consent," and of greater legal safeguards against the employment of young females in morally dangerous vocations.

Although in the British Army, both at home and abroad, much has been done by education, precept, and rational amusements for the men's leisure time to reduce the incidence of venereal disease in the troops, a very great deal has also been effected by improved medical treatment, and especially by the "continuous" treatment with intramuscular injections of mercury until a cure has been effected, to reduce sickness and invaliding from the syphilis that formerly contributed so largely to the wasting of the ranks. This method of treatment is now, however, used in conjunction with, or as supplementary to, the new anti-syphilitic remedy devised by Ehrlich, who, in the substance known as

dioxi-diamido-arseno-benzol ("606," or salvarsan), appears to have evolved a substance which is, on injection into the venous circulation, absolutely destructive to the specific organism; whilst, in the small doses of about 0·5 to 0·7 gramme required for this purpose, it is believed to be without actively injurious effect on healthy living tissues.

Gonorrhœa.—This disease is due to infection with the gonococcus. It can only be contracted by infection, usually during sexual intercourse. The possible after-effects of the disease in males are inflammation of the prostate, the seminal vesicles, the epididymis, the bladder, the ureters, stricture of the urethra, generalized pyæmia or septicæmia, and rheumatism of the joints. In females gonorrhœa is the commonest cause of sterility, and the bladder, the ureters, the ovaries, and Fallopian tubes may all become infected. Ophthalmia neonatorum is the most serious of the effects upon offspring of maternal gonorrhœa. As much as 25 per cent. of all the blindness in the community has been attributed to this disease.

The Royal Commission on Venereal Diseases (1916) recommended that the obligation should be impressed upon all doctors who treat venereal diseases to hand cards of instruction and warning to their patients, such cards being provided at the public expense. There should be power to secure the detention, if necessary, in Poor-Law institutions of patients suffering from venereal diseases. All advertisements of remedies for venereal diseases should be prohibited. Infectious venereal disease in any person should render such person legally incapable of contracting a marriage, a marriage so contracted being null and void. More careful instruction should be provided in regard to moral conduct as bearing upon sexual relations throughout all types and grades of education. No system of notification of venereal diseases should be put in force at present.

The Local Government Board issued Regulations (The Public Health [Venereal Diseases] Regulations, 1916) to carry into effect the recommendations of the Royal Commission, under powers conferred by the Public Health Act, 1875, the Public Health (London) Act, 1891, the Public Health Act, 1896, and the Public Health (Prevention and Treatment of Disease) Act, 1913. These Regulations are to be administered by County Councils, County Borough Councils, and the Corporation of the City of London.

Article I.—Every Council shall, subject to the approval of the Board, make arrangements for enabling any medical practitioner, practising in the area of the Council, to obtain, at the cost of the Council, a scientific report on any material from a patient suspected to be suffering from a venereal disease. *Article II.*—Every Council shall prepare and submit to the Board a scheme (*a*) for the treatment at and in hospitals or other institutions of persons suffering from venereal diseases; and (*b*) for supplying medical practitioners with salvarsan or its substitutes for the treatment and prevention of such diseases; and when the Board have approved the scheme, the Council shall make arrangements for carrying it into effect at the cost of the Council. All information obtained in regard to any person treated under a scheme shall be regarded as confidential. *Article III.*—Any Council may, subject to the approval of the Board, make arrangements for any of the purposes of this order with the managers of any hospital, institution, or society; but until the Board have approved of those arrangements and of the hospital, institution, or society, no expenditure shall be incurred. Any approval given by the Board may be given for such term and subject to such conditions as the Board may think fit, and any such approval may be withdrawn. *Article IV.*—Any Council may make such provision for the giving of instructional lectures and for the publication of information on questions relating to venereal disease, as the Council may think necessary or desirable.

Venereal disease in the order means syphilis, gonorrhœa, and soft chancre. The Regulations came into operation on July 12, 1916.

A large number of treatment centres (V.D. Clinics) have now been established throughout the country, and the increasing number of patients who seek treatment in them shows that the policy of free and secret treatment is a sound one. Great care should always be taken that men and women have no possibility of seeing each other, or communicating with each other, whilst waiting for treatment, otherwise the married woman and the respectable class of unmarried girls will not attend. In the larger clinics, where many attend, a social service worker should be present in the women's waiting room to preserve order and to assist my advice.

Whilst many patients persevere in the treatment until cured and released from attendance, a considerable proportion of careless patients who have acquired syphilis, on finding their symptoms

disappear after the first few doses of salvarsan or neo-salvarsan, consider themselves cured, and cease to attend. There is some reason to fear that such curtailed treatment may be followed by severe syphilitic recurrences affecting the central nervous system. Inadequate treatment of gonorrhœa is even more common, the complete eradication of this disease being often tedious and troublesome, particularly in women.

At a considerable number of treatment centres arrangements have been made by which irrigation or douching for gonorrhœa can be carried out daily for each patient by a trained orderly or nurse, under the supervision of the Medical Officer.

The intravenous injections for syphilis now in use are "606" and its substitutes, kharsivan and diarsenol, and "914" and its substitutes, neo-kharsivan, neo-diarsenol and nov-arsenobenzol. The number of persons treated with these arsenobenzol preparations who show any ill-effects of a toxic nature is small in proportion to cases treated. In most of such cases the ill-effects are slight and transient—*e.g.*, mild forms of dermatitis—but in a few cases more severe effects are recorded.

Whilst the provision of free and secret treatment for persons who have acquired venereal diseases is a very essential element in the campaign against these diseases, the prevention of disease is even more important. The diseases being for the most part spread by promiscuous sexual intercourse, the dissemination of knowledge as to how they arise, the advocacy of chastity, the provision of amusements, outdoor games, and social recreations which provide an interest in life for the young and inexperienced, are all measures upon which most people are agreed. For those people who have already run the risk of infection by promiscuous sexual intercourse there is also the opinion, held by many, that (having regard to the fact that infection may be obviated if within an hour or two of exposure the organs of generation are skilfully disinfected) it is not contrary to public morals to have available in public conveniences, or at other suitable places, what may be called "ablution centres," where specially trained attendants carry out the work of disinfection whenever called upon, day or night. At such ablution centres facilities for disinfection should be refused to those who present any symptoms of already acquired disease, and they should be referred to the Treatment Clinics. It is doubtful, however, if such ablution centres, even if generally established in large centres of population, would be much resorted

to by those who might benefit from them within the necessarily short limit of time after exposure to risk.

It is now generally established that if skilled disinfection of the generative organs is undertaken immediately after coitus, the risk of developing disease is almost entirely obviated, so far as the normal male is concerned, although there is considerable doubt as to the efficacy of the method for the female sex. This is called "personal prophylaxis," and is carried out by the application of an ointment containing calomel to the parts within reach, and by the injection of a solution of 1 in 1,000 potassium permanganate into the urethra (male) or vagina (female). Two questions arise in connection with "personal prophylaxis"—namely, (1) Is it effective when carried out by an unskilled person, even if he or she has received instructions as to the proper method of applying the medicaments? (2) Is the advocacy of such methods by the State or the Sanitary Authority in conformity with the code of public morality?

The experience of the British Army during the war shows that the system of ablution centres and the system of personal prophylaxis was each effective in preventing infection in men when thoroughly carried out. But in the army these procedures were backed by the authority of professional advocacy and skilled instruction and military discipline, and the conditions of success are not the same in civil as in military life. On the moral side of the question many people think that a propaganda carried on by the State or public authorities which advocates personal prophylaxis, and indicates how it may be carried out, would not only suggest to the public that such prophylaxis rendered promiscuous sexual intercourse a safe procedure, thus minimizing the deterrent of risk of infection, but would also tend to indicate that in the opinion of responsible authorities promiscuous intercourse is a necessary incident in the life of civilized communities which the State has recognized as uncontrollable and irremediable.

The considered view of the Ministry of Health is that it can give no countenance to the public advocacy of personal prophylaxis, and with this view the majority of the Public Health Authorities of the country appear to be in agreement, although many individuals think that an experimental trial of the prophylaxis in great military and naval centres is justifiable.

An important piece of legislation, the Venereal Diseases Act, 1917, imposes severe penalties upon anyone who, not being a duly

qualified medical practitioner, either directly or indirectly and for reward treats, prescribes for, or advises any person suffering from these diseases, or who advertises any such treatment or advice.

The scheme for controlling venereal disease in Great Britain is not regarded as by any means complete, and suggested extensions of the scheme are receiving much consideration. There is certainly a growth of opinion in favour of the segregation, where necessary, of mentally deficient adolescents; legal powers for compelling treatment (even by detention in hospital) where the patient refuses to continue treatment until no longer infective, and continues recalcitrant despite all other efforts; further legal provision to deal with those who are known to be suffering from venereal disease, and are likely to infect others; measures for preventing, so far as possible, the marriage of any person who is in an infective state; the making of the clinics more available by keeping them open almost continuously, and offering facilities at these clinics for the prompt and skilled disinfection of those who have exposed themselves to infection. Many of the above measures have been put in force outside Great Britain, but it is too early to judge of their actual value in practice. In view of the national interest in the stamping out of these diseases, the expense to the taxpayer and ratepayer of the schemes of local authorities, and the fact that in the majority of cases the patient has only himself to blame for his trouble, there is at least a case for the promotion of compulsory legislation. It should be stated, however, that there are many who take the view that compulsory measures with reference to these diseases will defeat their object and prove of little value, and that it will be wiser to rely upon a more widespread provision of facilities for treatment and a more extended educational campaign. It is certain that outside large urban areas satisfactory results must, in great measure, await the time when all general practitioners are familiar with the newer methods of treatment and apply them in their practices.

Tropical Diseases.

Asiatic Cholera.

Cholera is endemic in the delta of the Ganges, and probably also in other parts of India and the Orient. Epidemic extensions take place from time to time, the disease being imported from

these "homes of cholera" into far distant countries, by sea or overland, by means of persons suffering from it, and possibly by means of carriers and infected articles.

The three main routes which cholera has taken from the endemic area in India to Western Europe are as follows: (1) through the north-western provinces of India to Afghanistan, and thence by caravan routes to Khiva and Russia; (2) from Southern India up the Gulf of Persia, and thence to Syria and Egypt, and across Persia to the Caspian Sea; (3) mainly by pilgrim traffic to the Red Sea ports and Egypt, and thus to the Mediterranean.

The usual mode of propagation of cholera is through drinking water. The specific poison is contained in the copious bowel discharges of the sick, and may find its way through the soil on which the dejecta are thrown, into streams, wells, or tanks. It is also possible that the contagion is at times transmitted through the air by the dried choleraic discharges being borne into the air by currents of wind; although the fact that the cholera germs are rapidly killed by drying is opposed to this view. If flies feed on infected material, the organisms may be found in them twenty-four hours afterwards. Haffkine also has shown that in an infected district flies can contaminate milk with cholera spirilla, if the milk be kept in open vessels; so that it seems probable that cases of apparent transmission of the disease through the air may in reality be due to the agency of flies.

It is probable that, as in enteric fever, the spread of cholera is largely facilitated by mild, unrecognized cases and by carriers; but the subject of the influence of such means in the spread of the disease has not so far been elucidated in so complete a manner as has been done in the case of enteric fever.

Temperature and moisture are controlling factors of great importance. When the disease is imported into a temperate climate, the intensity of the epidemic is invariably felt in the late summer and autumn, and dies away with the approach of cold weather, possibly to again acquire epidemic intensity in the following summer. It is evident, therefore, that the specific virus can only attain its full virulence where the temperature of the air, and therefore of the soil, is sufficient. The combination of moisture and heat of soil, characteristic of the Ganges delta, appears to offer the most suitable environment for the cholera virus.

In India, Cunningham has shown that the comma bacilli, which are found in the evacuations of cholera patients, and which are regarded as the specific cause of the disease, when introduced into polluted water or soil, tend rapidly to disappear, as they are attacked and destroyed by the saprophytic bacteria always present in such circumstances; but in some cases they have been found alive even after two or three months in cholera dejecta kept at room temperature.

The incubation period of cholera is usually very short—one or two days; but it may occasionally be prolonged for ten days or more. The evacuations are most infective during the height of the disease. In epidemic periods the proportion of deaths to attacks is greatest during the period of maximum intensity of the epidemic. When the epidemic is first commencing, and after it has begun to subside, the recoveries may considerably exceed the numbers of deaths.

The preventive measures which have hitherto acted most successfully in keeping the disease out of these islands have reference to our "first line of defence," *i.e.*, the coast. By far the most important are contained in the provisions of the Cholera Order of the Local Government Board, but other valuable measures have been: (1) the Order prohibiting the importation of rags from all infected ports; (2) the Order prohibiting the landing of "filthy and unwholesome aliens," unless they first satisfy the Medical Officer of Health of their freedom from cholera, and give their names and destinations; (3) the provision of the means of isolating the infectious sick at our ports; (4) the placing of these ports in a good sanitary condition by dealing with insanitary dwellings and areas, so as to remove, as far as possible, all dangerous breeding grounds for the germs; and (5) the adoption of every possible precaution to safeguard the purity of public water supplies.

The issue of printed notices by the local authority, in which instruction is given as to the means to be adopted by the individual to guard against infection, is a useful measure. In such handbills it should be stated that raw vegetables and fruit should be avoided; that extreme cleanliness in the household should be adopted, since cholera is essentially a filth disease; that all milk and water should be boiled shortly before use; and that on the occurrence of diarrhœa in any individual, medical advice should be at once sought.

When the danger of an outbreak becomes imminent in any district, a staff of nurses should be enlisted, arrangements made for the use of any available buildings as temporary hospitals, a large stock of disinfectants provided for gratuitous distribution, and measures taken for the supply to medical practitioners of anticholera inoculations.

Outbreaks of cholera have often been preceded by sporadic cases of severe diarrhœa, which are probably unrecognized cases of the disease.

The provisions of the Cholera Order have supplanted those of Continental quarantine in these islands, and are doubtless far more successful in practice. The facts which tell against the efficiency of quarantine, as practised elsewhere, are certainly sufficiently strong to warrant the adoption by all countries of the English system. The detention of persons on board an infected ship for many days is not a measure calculated to protect the healthy from infection and to limit the spread of the disease, whilst the delays thus caused are ruinous to trade. Such measures have been shown to be unnecessary in this country, and, owing to frequent evasions, they often fail in their object of keeping the disease out of foreign ports. In Malta the provisions of Italian quarantine continue to be practised, but the British system is in application at Gibraltar; the result is that Gibraltar generally escapes from imported infectious disease, whereas Malta almost invariably suffers. A very vigorous system of quarantine, moreover, utterly failed to prevent cholera crossing the great natural barrier afforded by that huge inland sea, the Caspian, when the disease appeared on its eastern shores on the occasion of the last great visitation of cholera to Europe.

Land quarantine—by which is implied the drawing of a cordon of soldiers or police round an infected area—generally also fails in its purpose.

Anti-cholera inoculation, originally introduced by Haffkine in 1893, is now extensively employed as a prophylactic for those who are at all likely to be exposed to cholera infection. Several strains of cholera vibrios are used, and grown for 48 hours in pea-extract agar. The emulsion is heated to 55° C. for one hour to sterilize the bacilli, and 1 per cent, carbolic is added. The sterilized emulsion is diluted so as to contain 8,000 million bacilli per c.c. of saline and 0·5 per cent. carbolic. The dose for pre-

ventive inoculation is ½ c.c. subcutaneously, followed by 1 c.c. after an interval of seven to ten days. The local reaction is generally very mild. The immunity produced lasts only three or four months. During the Great War many millions of anticholeraic inoculations were made, and the value of the prophylaxis was generally recognized.

In cholera-stricken villages wells should be treated with potassium permanganate (1 ounce to 2,000 gallons) until the water is pink, and not used for drinking for 24 hours; or chlorinated by bleaching powder so as to produce 1·3 parts of chlorine per million of well water.

Dysentery.

This is not a disease of common occurrence in this country, except perhaps in lunatic asylums, where it is known as colitis. It is distinguished clinically from acute diarrhœa (summer diarrhœa, English cholera) by the fact that the stools contain slime and blood, and there is much tenesmus. The disease also has a great tendency to become chronic, which is unusual in summer diarrhœa.

Dysentery is a very common and fatal disease in tropical countries. In temperate climates it is rarely seen except in times of war or famine. It is intimately associated with conditions of defective hygiene, *e.g.*, fouling of the water supply or of the soil in the neighbourhood of habitations by excreta, overcrowding in houses or in camps, and insufficient, coarse, or bad food. In tropical and sub-tropical countries, where these insanitary conditions, or some of them, continuously prevail, dysentery tends to become endemic, and to assume epidemic proportions, if circumstances are favourable to its spread.

Dysentery is undoubtedly to a large extent a water-borne disease, like enteric fever, but, like the latter disease, its propagation is at times effected by means of dust and flies. Much light was thrown on these methods of dissemination of the disease during the South African Boer War. As in cholera and other tropical diseases, chill, bad or irritating food, alcohol, mental depression, etc., play a very important part as predisposing causes.

The clinical conditions we call "dysentery" may arise from several causes. It may be bacillary or protozoal in its origin. The bacillary type may be due to Shiga's bacillus, or it may be due to one of the several members of the Flexner group. The

protozoal type appears to be chiefly due to the *Entamœba histolytica*, but possibly it may also arise from flagellates—*e.g.*, *Lamblia intestinalis*—and ciliates—*e.g.*, *Balantidium coli*. Up to the present epidemic dysentery in Great Britain has chiefly affected asylum populations, and although Shiga's bacillus has occasionally been reported as the cause of outbreaks, these have generally been shown to be due to *B. dysenteriæ* (Flexner). Such cases in children are probably not at all uncommon in this country; and the presence of blood and mucus in the dejecta should immediately suggest the dysenteric nature of the malady, and the necessity for careful therapeutic and hygienic measures. There is no evidence that protozoal dysentery in epidemic form has occurred in England, and it is certain that the bulk of these sporadic cases are imported.

The carrier problem in the case of dysentery is of great importance. In bacillary dysentery the specific organisms may remain in the body after the cessation of symptoms, not uncommonly for three months; and in amœbic dysentery it has been proved that carriers may have recurrent diarrhœal attacks for several years. The only quick and ready means for the diagnosis of latency in these cases is the differential leucocytic count, the important feature being an increase of the mononuclear leucocytes without there being distinct evidence of malarial or other protozoal blood infections. Such an observation should lead to most careful and repeated microscopical examinations of the fæces after the administration of a purgative. Doubtless the relapsing carrier, who probably excretes as many bacilli as the primary cases, is a serious source of danger as regards bacillary dysentery. The dissemination of the disease appears to depend chiefly on defective personal hygiene, hence its presence in asylums and its liability to spread amongst children.

The intestinal protozoa of man spread their infection by means of encysted forms which, as far as we know, undergo no development outside the body, but vegetate in water until they are ingested by another individual, when the contents of the cyst divide into small amœbæ, which escape into the intestine by rupture of the cysts. Therefore the infection of *Entamœba coli* is most readily recognized by the detection of characteristic cysts, which are clear, refractile, spherical bodies with a very sharp outline, and readily seen with one-sixth inch objective. Of all the intestinal protozoa of man, *Entamœba histolytica* is

the most dangerous, as being the cause of amœbic dysentery and liver abscess. Apparently carriers may maintain their infections for long periods, during which time they are constantly passing exceptionally resistant cysts, sometimes in enormous numbers.

In dysentery, chronic urinary carriers are rarely if ever found, and the bacilli present are few in number in the case of chronic fæcal carriers. Therefore chronic dysentery carriers are probably less dangerous than chronic enteric carriers. Acute carriers of dysentery are fairly common, but the bacilli are not usually present for more than three or four weeks after convalescence. As in the case of enteric, highly-trained nurses are needed in this disease, and the sufferers must be separated from patients with other diseases. Moreover, no patient from either of these diseases should be discharged from hospital until at least two bacteriological examinations of his dejecta have been made, at intervals of one week, with negative results; and these examinations must date from the period when the patient has been placed on full diet and his stools are normal. His departure from hospital should be notified to the local Medical Officer of Health, and precautions must be taken against him being employed in the handling of food or the purification of drinking water.

Flies of various kinds undoubtedly act extensively in the propagation of dysentery. Within twenty minutes of feeding on dysenteric excreta containing the cysts of *Entamœba histolytica*, flies begin to discharge unaltered and living cysts in their fæcal deposits. Such deposits excreted upon food would render it capable of infecting healthy persons. It is unlikely that the cysts are carried on the outside of the fly, as flies continually clean their legs and wings, and the cysts die when dried.

Emetine, the alkaloid of ipecacuanha, acts as a specific germicide on the *Entamœba histolytica*, while bacillary cases have been treated with great success by means of polyvalent sera derived from horses immunized by the injection of the bacillus of Shiga and of various Flexner strains. Efficient emetine treatment, before discharge from hospital, prevents the patients of amœbic dysentery becoming cyst carriers except in a few cases. The cysts of histolytica can probably survive for several weeks in water, or elsewhere, if not allowed to dry too much. Indiscretions in diet, the abuse of alcohol, and especially getting wet and chilled, may light up an acute exacerbation with a return of blood and

mucus in the stools, the parasite being found in the vegetative state. The examination of dysentery convalescents six months after the onset of illness has led to the discovery of as many as 20 per cent. of carriers, who are potential sources for the outbreak of fresh infection. Of prophylactic vaccination against bacillary dysentery little is known; the chief difficulty is the intense toxicity of the Shiga strains of bacillus both for animals and for man.

The *Amœba coli* is very frequently found in the contents of the liver abscesses, which are so often associated with chronic dysentery, and this indicates the presence of amœbæ in the intestinal tissues around dysenteric ulcers.

In some cases of colitis, or asylum dysentery, in this country Durham has isolated a micrococcus, so minute that it readily passes through a Berkefeld filter, from the blood, liver, spleen, kidney, and bile of affected patients.

Plague.

An epidemic disease having the character of bubonic plague is referred to by many old writers, as far back as 2,000 years ago, as prevalent in Egypt, Libya, and other parts of North Africa. The most appalling European visitation was that in the fourteenth century, known as the "Black Death," which was supposed to have had its origin in China in 1334; this outbreak lasted many years. The Great Plague of London made its appearance in 1664, lasted about one year, and destroyed at least 63,000 persons.

China and the western parts of India appear to have always suffered most; and it is generally recorded that plague has attacked districts for a number of successive years, with short intervening periods of apparent freedom.

China does not seem to have suffered much in recent years. For example, it has not been present in Pekin, Shanghai, and other large towns, but only in Hong Kong. Occasionally from here it has found its way to Canton and Macao by direct intercourse, but even then it appears not to be able to get a footing.

Although rare in equatorial regions, it occurs in hot and cold weather, wet and dry seasons, on dry and damp sites, and at all altitudes. In India plague generally decreases during the hottest weather, and recrudesces with the onset of the colder seasons.

The disease is of microbic origin, and is due to the bacillus isolated at Hong Kong in 1894 by Kitasato and Yersin. This bacillus is found post-mortem in the blood, the spleen, and other internal organs, also in the unopened buboes, the sputum, fæces, and urine. The infection can be contracted by inoculation, inhalation, or by swallowing, and human sufferers are not the sole carriers of contagion. Rats, mice, marmots or tarbagan (Mongolia), ground squirrels (Caucasus and California), bandicoots, guinea-pigs, monkeys, pigs, and probably sheep, goats, dogs, and other animals, may also suffer from the disease, which in China and the Himalayas has long been called the "rats' disease." Fleas and flies have been shown to die in large numbers in plague laboratories, and to contain the *Bacillus pestis*. Like mosquitoes, they may act as carriers. There is evidence to show that black or Indian rats may be affected before human beings; and it is certain that the continuance and spread of the disease is favoured by the presence of these highly susceptible animals, many outbreaks having been attributed to infected rats, conveyed from an infected to a non-infected port in grain-carrying ships. It is practically certain that the infection is conveyed from rat to rat, and from rats to human beings by means of fleas, and that on the death of a plague-stricken rat, the fleas—already engorged with bacilli—leave the body and find their way into houses, where they attack man, inoculating him through the "bites."

It is also highly probable that inoculation of man occurs through the excreta of fleas, which swarm with *B. pestis* in infected insects. The flea deposits excreta on the human skin, and inoculation takes place when the skin is scratched with the finger-nails to allay irritation. The bacilli so inoculated are carried by the lymphatic vessels of the skin to the lymphatic glands (usually of the groins or armpits), as the legs and arms are most likely to be flea-bitten.

The flea (*Zenopsylla cheopis*) of the black or Indian rat (*Mus rattus*) closely resembles the common flea of man (*Pulex irritans*), but is smaller and of lighter brown colour. The black or Indian rat is essentially a house-rat, and lives in close association with human beings. As the natives of India and the East live very commonly in rat-infested houses, plague is especially a disease of the natives. The houses of Europeans in tropical countries are either so constructed as to be rat-proof, or rats are exterminated and not allowed to multiply in European residences. The

flea (*Ceratophyllus fasciatus*) of the brown or European rat (*Mus decumanus*) is not known to be concerned in the transmission of plague from rat to man in anything like the same degree as the flea of the black rat; but it may transmit the disease from rat to rat in England and other countries, and occasionally it may convey the disease from rat to man. The brown rat, which is larger and fiercer than the black rat, was introduced into England in the eighteenth century, and gradually drove out and partially exterminated the black rat, which was the original inhabitant of the British Isles. The brown rat is not a house-dweller like the black rat, but lives in out-buildings, ditches, drains, or the open country; consequently it does not come into close association with man like the black rat. This may be the chief reason why the occurrence of plague in the rats of a locality in this country is not followed by an epidemic amongst human beings, as so frequently occurs in India.

Klein states that the *B. pestis* as found in the rat is of a different type to that isolated from man. The human type is much more virulent than the rat type, and they present also permanent and definite differences in morphological, cultural, and physiological respects. The rat type quickly loses its virulence when sub-cultured artificially, whereas the human type retains its virulence for long periods during sub-culture, and, unlike the rat type, recovers full virulence by a renewed passage through the animal body. The original virulence of the rat type, when once lost, cannot be regained by animal passage.

Direct contagion from the sick to the healthy appears to be a minor cause for spread, Europeans having suffered but very little while in attendance on Indian patients. Like typhus fever, plague appears to be associated with conditions of poverty, filth, and overcrowding, and with soil polluted by organic matter, but the chief cause of bubonic plague is undoubtedly the inhabiting by human beings of rat-infested dwellings. It has not yet been demonstrated that drinking water has acted as a disseminator of the virus, although experiments show that the plague organism can live for a long time in water. Fomites retain and spread the infection.

There are three distinct types of the disease—the bubonic, the septicæmic, and the pneumonic; but the first named is so much more common than the others that the disease is very generally known as " bubonic plague."

It has been noted in the Transbaikal district of Siberia, where in winter the houses are often densely overcrowded, unventilated, and very filthy, that the bubonic form of plague tends to become transformed into the septicæmic, and this later into the pneumonic form. This form spreads with extraordinary rapidity, as it is a direct infection from man to man, and follows the lines of human travel (G. L. Tuck).

In pneumonic plague the bacilli of plague are found present in large numbers in the sputum and in the droplets of foam or froth ejected from the lungs during coughing. This form of the disease is therefore highly contagious, and no one should approach a case of pneumonic plague without the protection afforded by a well-fitting mask over the face, nose, and mouth. The septicæmic form of plague must also be regarded as highly infectious.

The incubation period of bubonic plague varies from two to seven days; and generally within twenty-four hours, or less, from the onset of symptoms the buboes appear in the groin, the armpit, the region of the neck, or more rarely elsewhere. Death frequently takes place within forty-eight hours of the onset of symptoms, a fatal result being rare after the eighth day. The disease varies so much in its clinical aspects and severity as to justify a rough classification of cases into severe and mild (pestis major and pestis minor); but the tendency nowadays is to restrict the term pestis minor to cases of enlargement of glands (not venereal in origin), which are often seen just before and during a true outbreak of plague, and in which the *B. pestis* cannot be demonstrated.

The preventive measures against the disease include: The compulsory notification of the disease, the discovery of cases by house-to-house inspection (where necessary), and the early bacteriological diagnosis of the mild or "ambulant" types of the disease which have been observed to precede an outbreak.[1]

[1] The following directions for obtaining and forwarding for bacterioscopic examination material from a suspected case of plague, have been issued by the Medical Officer for the Local Government Board:

(*a*) From the living person:—

1. Clean with soap and water and then with alcohol the last phalanx of either the second or third finger. When dry, or after mopping with a clean cloth, put a piece of tape round the proximal end of the last phalanx so as to cause a venous congestion. Prick the palmar surface of this phalanx with a sterile needle, and immediately take up the exuding blood in two sterile capillary tubes such as are used for collecting vaccine lymph. These tubes when charged should be sealed at both ends.

Prompt and efficient isolation and disinfection should follow upon the discovery of the cases; and those living in the same house with a plague patient (the so-called " contacts ") should be removed from their homes to a quarantine house, to be kept under observation for ten days. Both prophylactic and curative inoculations with Haffkine's vaccine and Yersin's plague serum, respectively, are further measures of undoubted value, which should be practised when possible. The total destruction of the rats in an infected area is eminently desirable to check the spread of the disease, but the due execution of this precaution has hitherto presented insuperable practical difficulties. People should be advised to keep their houses rat-free, by domestic cleanliness and the frequent collection and disposal of house-refuse; to provide no food for rats; to keep dogs or cats; and buildings should be maintained as rat-proof as possible. The number of rats may be materially reduced by trapping or poisoning, by hunting with dogs and ferrets, or by asphyxiating them in their hiding-places with a mixture of carbonic acid and carbon monoxide gases, or with sulphurous acid gas; bolting-holes should be netted, and the dead bodies of those that die should be immediately burned. There are many different kinds of trap in use: The steel gin trap (unbaited and placed lightly covered upon rat-runs), a baited break-back trap, and the varnish trap.

The baiting and trapping of rats is never successful beyond a certain point, for rats are intelligent, and they quickly leave areas where they are being harassed. One of the most effective and cheapest poisons is barium carbonate. One part of $BaCO_3$ to five parts of oatmeal, mixed with water to a stiff paste, and spread on bread and butter, will often succeed in poisoning rats. Before they die the animals generally come out of their burrows

2. When there is a discharging bubo, collect fluid therefrom in capillary tubes as in the case of blood. When this discharge is not of a sufficiently fluid character for collection in this way, place some of it in a small glass-stoppered phial, previously well washed out with alcohol, care being taken that no alcohol remain in the phial.

3. If expectoration be obtainable, collect some in a phial in the manner prescribed in Section 2.

(*b*) From the dead body:—

1. Cut out any inflamed lymph-gland, together with some of its surrounding tissue, and place the whole in a wide-mouthed, glass-stoppered bottle, previously well washed out with alcohol, care being taken that no alcohol remains in the bottle. The bottle should have the stopper well secured and sealed.

2. Obtain also a piece of the spleen, dealing with it in the same manner.

into the open for water. Squills are also now in use as a rat poison. The form and appearance of the bait must be frequently varied, otherwise rats will disregard it. Baits containing phosphorus have been very successful; but great care must be taken to guard against accidents. A method of rat destruction which has met with some success is to place typographic varnish—a most adhesive substance—on strips of cardboard, and lay these strips in rat-infested places. A rat walking or running over the varnish is caught by his feet, and is unable to release himself. In towns it is important to keep the sewers well cleansed and flushed, so that rats may not have supplies of food in the sewers; and sewers and house-drain branches into them should be well constructed to prevent rats leaving the sewers in search of food.

Efforts have been made with some success to communicate an epizoötic disease to rats and mice by means of the Danysz bacillus, the Liverpool virus, and ratin, which, while not communicable to man, would spread among the rodents and cause their destruction. Whatever methods are adopted to destroy the rats in a particular area, it is desirable that the active campaign should begin at the periphery of the area and work towards the centre, and that all the premises in one block of buildings should be dealt with at the same time.

The Rats and Mice (Destruction) Act, 1919, requires occupiers of premises and land to prevent these from becoming infested, and when after notice by the local Sanitary Authority the occupier remains in default, the local authority may take all reasonable measures for rat-destruction and rat-proofing, and recover the cost from the occupier.

The Danysz bacillus is genetically related to the paratyphoid group of organisms, which also includes the *Bacillus enteritidis* of Gaertner. Some care should be exercised in the destruction of rats by means of food which has been soaked in cultures of the Danysz bacillus, as there is reason to believe that human beings have been rendered ill by contamination of their food with this bacillus. There is some reason to question the accuracy of the statement that the Danysz bacillus is harmless to man.

Merchant vessels should take the necessary steps for the destruction of rats on board before loading and upon discharge, and also to prevent intercommunication during loading and discharge between ship and shore rats. Further, owners of riverside warehouses and granaries should make systematic efforts

to exterminate rats, and to prevent rats leaving ships; cables covered with fresh tar at each end and fitted with special conical guarded collars should be used, and foot-bridges should be raised during the night. Fumigation with sulphurous acid gas effectually destroys rats in a closed hold, but this can only be used after the hold is cleared out, because of its injurious effect upon many cargoes. The admixture of CO_2 and CO, obtained from burning charcoal, is cheap and without injurious effects upon the most delicate goods; it is, however, a most dangerous gas to human beings, and extreme precautions must be taken against accidents. Any rats found on a "suspected" vessel must not be handled, but plunged with tongs into a bucket of carbolic solution until they can be burnt. No rats must be thrown overboard into the harbour.

The evacuation of infected houses, and even of infected districts, has been attended with good results in India, the people being housed temporarily some distance away, while the sufferers are isolated, and the infected clothes and premises disinfected. To guard a district against the importation of the disease, all persons coming from infected localities should be subjected to at least seven days' surveillance; and provision should be made for the medical inspection of all incoming persons at the railway centres, and at other means of approach to the district. Anyone found to be suffering from the disease must submit to hospital isolation, and suspects must be detained temporarily in quarantine camps. As the disease is essentially a filth disease, every effort should be made, by improved scavenging and the removal of insanitary conditions, to stamp out the possible foci of infection. Experiments have shown that a soap emulsion of kerosene oil is a valuable agent in the disinfection of plague-infected rooms; and the fleas exposed to the action of this pulicide are almost always killed in two minutes.

Haffkine's prophylactic against plague consists of a fluid prepared by growing plague bacilli in goat, beef, or mutton broth on which floats a small quantity of clarified butter. The bacilli attach themselves to the oil globules, and form stalactitic growths projecting into the broth. After about four weeks, when six crops of stalactites have been formed, the culture is heated to 70° C. for an hour, to kill the *B. pestis*, and a little weak carbolic acid solution is added to prevent the growth of extraneous organisms. A copious deposit is produced which

should be well shaken and diffused throughout the liquid before the vaccine is finally bottled. The usual dose for inoculating an adult is 2 to 3 c.c., and the inoculation should be repeated in from twelve to twenty days. A good deal of reaction results, the temperature rising to 102° F., sometimes to 104° F., with a feeling of general malaise and pain at the seat of inoculation. The India Plague Commission has recently reported that inoculation of Haffkine's fluid sensibly diminishes the incidence of plague attacks, and also the fatality of attack among the inoculated population.

Yersin's serum is prepared in the same way as diphtheria antitoxin, by inoculation of horses with living cultures of plague bacilli. The immunity given by inoculation of Yersin's serum is of much shorter duration than that due to affkine's prophylactic. Fifteen days is about the limit of the immune period due to the serum, whereas Haffkine's fluid may be protective for several months; but it is claimed that Yersin's serum is also curative, when once the disease has declared itself.

Rat-bite Fever.

This is a specific infectious disorder of rare occurrence which may follow on the bite of a rat. The specific organism concerned is a spirochæte, *Leptospira morsus-muris*, and the usual symptoms are irregular fever and a rash. The disease is of low fatality.

In addition to being concerned with plague and rat-bite fever, rats often contaminate food, and may in this way be a source of trichiniasis and round worms. Their natural environment is garbage and filth, and wherever they go they are apt to carry dirt with them.

Malaria.

It has now been demonstrated (Manson, Ross, Koch, Grassi, Celli) that man is the temporary host, and the mosquito the definitive host, of all known malarial parasites. In addition to man, however, monkeys, bats, and other vertebrates may harbour the parasite; and Manson suggests that in the absence of vertebrates, one mosquito may become directly infected from another, and so keep the parasite alive. These parasites pass their asexual life, and prepare their sexual forms, in the human blood, while they complete the sexual cycle of life in the middle intestine of the mosquito. Those mosquitoes capable of affording

lodgment to the specific parasites, and of infecting man by means of their punctures, appertain to the genus Anopheles.

Although malaria extends from the Arctic circles to the tropics, in the colder latitudes it is found chiefly during the summer and early autumn, and the association with swampy ground is usually marked, whilst the type of disease tends to be mild. In warm latitudes the disease is often perennial, although the season of the rains (monsoon) or following the monsoon is generally the most malarial. The type of disease is more often malignant than in cold or temperate latitudes. A condition everywhere precedent to the development of malaria is a sustained average temperature of at least 60° F. At lower temperatures the malarial parasite undergoes no development in the mosquito. Even as far south as southern England there are only a few weeks (less than six) in the summer from July to September when the mean daily temperature exceeds 60° F., except in abnormally hot seasons. Anopheles mosquitoes are often found in swampy areas in England, but the comparatively low summer temperatures, and the general absence of malaria-infected individuals in the populations of swampy districts, accounts for the freedom of this country from malaria. It has not, however, always been so, and going back 100 years and more ague figured largely in the old bills of mortality.

Structurally the mosquito consists of a head, to which are attached the eyes, two antennæ (long, feathery appendages), two palpi (feelers of varying length), and the proboscis, by which the insect pierces the skin and sucks blood from its victim. The thorax comes next to the head, and has attached to it three pairs of long, jointed legs, and one pair of membranous wings. The segmented abdomen is attached to the thorax. The best known of the malarial mosquitoes is the *Anopheles maculipennis* (spot-winged Anopheles). These insects may be distinguished from most other mosquitoes by both sexes having palpi as long as the proboscis, which is straight; by having spotted wings; by the fact that, when at rest on a flat surface, the long axis of the body is almost vertical to the flat surface, whilst in most other mosquitoes it is parallel. Anopheles, moreover, do not make so loud a humming sound when in flight as other species do.

Mosquitoes, like other insects, are propagated by eggs, which in their development pass through two stages, that of *larva* and that of *pupa* or *nymph*, before the perfect insect emerges. Almost all mosquitoes are aquatic in their larval and pupal stages, and

any small collection of water may form their breeding-ground. In the absence of ponds, ditches, surface pools, exposed cisterns, water-butts, or rejected tins and cans capable of holding water, mosquitoes cannot propagate, and die out. In streams or ponds containing fish the larvæ are often consumed by the fish, and but few adult mosquitoes may develop. The eggs are laid by the female mosquito on the surface of the water either singly (*Anopheles* and some species of *Stegomyia*), or cemented together in hundreds (*Culex*), so as to form rafts, which float on the surface, as do the single eggs, each being provided with an air cell.

A few days after the eggs are deposited, the larvæ are hatched out. These are very similar in all species of mosquito, and consist of a head, thorax, and segmented abdomen without any legs. The larva of *Anopheles* lies almost horizontally beneath the surface of the water, as it breathes air in through an aperture placed dorsally at the posterior half of the abdomen; whilst in *Culex*, *Stegomyia*, and other forms, there is one long air tube at the end of the abdomen, which enables the larva to breathe whilst its body is immersed. The larvæ can, therefore, be destroyed in small collections of water by floating some light oil, such as paraffin, on the surface of the water, which prevents the absorption of air through the breathing pores. This is one of the anti-malarial measures undertaken, where it is impossible to drain away or otherwise abolish the surface or collected waters which form the breeding-grounds of mosquitoes.

The mode of production of malaria in man is briefly as follows: In an infected Anopheles mosquito the veneno-salivary glands lying on each side of the fore part of the thorax, and the ducts leading from these glands to the base of the mosquito's proboscis, contain the spindle-shaped sporozoites (malarial). When the infected female mosquito bites a man, these sporozoites are injected into his blood. In the blood the sporozoites multiply, find entrance into the red blood corpuscles, and grow at the expense of the hæmoglobin, so as to be recognizable as malarial parasites eight to ten days after infection. The parasite is then seen as a pale, ill-defined disc of protoplasm occupying a larger or smaller area of the red corpuscles, and containing a number of black pigment particles—melanin. These scattered pigment groups subsequently concentrate into one or two larger central groups, around which the protoplasm arranges itself

in minute segments, which finally become spores. The blood corpuscle then breaks down, and the spores and melanin are liberated into the liquor sanguinis. The melanin and some of the spores are then absorbed by the phagocytes, but others of the spores attach themselves to undamaged red blood corpuscles, which they enter. In these newly infected corpuscles the parasites exhibit active amœboid movement, shooting out and retracting long pseudo-spodia, and grow at the expense of the hæmoglobin. As the parasite becomes larger the amœboid movements lessen, and just before sporulation and the completion of the asexual cycle, the parasite is passive.

At a later stage of the malarial illness, certain sexual forms of the parasite may be seen in the blood, these assuming either the form of crescents (malignant ague) or large intra-corpuscular forms (benign ague). In the male type of crescent the protoplasm is hyaline, and the pigment loosely arranged; in the female the protoplasm is faintly granular, and the pigment arranged as a well-defined ring about the centre of the parasite. If human blood containing these crescents or large intra-corpuscular forms is ingested by the female Anopheles mosquito into its stomach, certain changes take place. In the male crescents or parasites active movements set in in the pigment, and one or more flagella are suddenly shot out from the periphery of the parasite, which have characteristic waving movements. Some of the flagella break away, and approaching the female parasites enter their substance through a minute papilla on the surface. Only one flagellum enters each female; no second flagellum can effect an entrance. After impregnation the female parasite assumes a vermicular form, and becomes motile. It then penetrates the wall of the mosquito's stomach, and lodges itself amongst the muscular fibres, and may here be seen as an oval or spherical body with sharp outline, thirty-six hours after the mosquito has fed on infected human blood. During the next few days a vast number of minute, slender, spindle-shaped nucleated bodies—the sporozoites—are developed in the parasite, now much enlarged; a week later the capsule containing the sporozoites bursts, and the latter are discharged into the mid-gut of the mosquito. From here they pass by means of the blood stream into the veneno-salivary glands, and the sexual cycle is completed.

Typical ague is either "quartan"—pyrexial attack every

seventy-two hours; "tertian"—every forty-eight hours; or "quotidian"—every twenty-four hours. The rigors introducing the attack coincide in point of time with the liberation of the spores from the red corpuscles; and it is believed that the fever is determined by the setting free of the toxins generated by the parasites in the blood corpuscles. During the hot and sweating stages of the attack it is probable that the toxins are in process of elimination from the blood. During the intervals between the attacks there occurs the infection of red corpuscles not previously affected, and the growth, maturation, and sporulation of the parasites within the corpuscles. In the remittent and continued (malignant) types of malaria, there has probably been a mixed infection with parasites belonging to the various types of ague above mentioned, together with the malignant crescent-forming parasites, so that sporulating parasites may be met with at all stages of the disease, and the fever is not intermittent, but continued with remissions.

Blackwater or Hæmoglobinuric Fever sometimes occurs in those who have been subject to occasional attacks of malarial fever. This disease is very frequently fatal; but, if recovered from, the malaria parasites, which were present in the blood prior to attack, generally disappear during the process of hæmoglobinuria, which may thus terminate for good a chronic malarial infection. The hæmoglobinuria secures the destruction of all the parasite-infected red corpuscles, and their included parasites, and therefore seems to be a method of spontaneous cure of a malarial infection. Nothing is known as to the cause of the occurrence of blackwater fever, apart from its association with malarial parasites in the blood.

Although in most cases blackwater fever occurs in those who already harbour the malignant (subtertian) malarial parasite, yet many cases have been reported in robust individuals who were attacked within two or three months of arrival in a blackwater fever country, and who were quite free from malarial antecedents. It is possible, therefore, that the disease is not at all related to malaria, but is caused by a species of piroplasmata similar to those that cause hæmoglobinuric fever in cattle, sheep, and horses (see p. 595). The piroplasmata infection may remain latent in the system for some time, and only be roused into action by chill, shock, overdosage with quinine, or over-exertion. Antecedent subtertian malaria may also predispose to an attack

of blackwater fever if the individual has already received the infection of piroplasmosis.

The soil plays only an indifferent part in the propagation of malaria, by its favouring or otherwise the life and development of the malariferous mosquitoes. The most favourable soil for malaria is that which permits of the formation and continuance of pools of stagnant water containing algæ or water weeds, which are the habitat of the eggs, larvæ, and nymphæ of the genus Anopheles. Rice fields, whether the water is stagnant, running, or intermittent, always afford a favourable nidus for the Anopheles larvæ.

It is generally admitted that chilling of the body predisposes both to the onset of the primary infection and to relapses. The inhabitants of malarious districts in the tropics acquire some degree of immunity, as a rule, after a few years of life in these regions. Among prophylactic methods should be included the ability to make an accurate diagnosis of the complaint, and to recognize the plasmodium in blood submitted for examination. After diagnosis the patient should be isolated, if possible, in some place where malarial mosquitoes do not exist, for he is otherwise liable to be bitten by infected mosquitoes, and thus to become the subject of contemporaneous infection by various different malarial parasites. Moreover, mosquitoes which feed upon him are capable of disseminating the disease; for, by reason of the sexually developed parasites in his own blood, he is a source of infection to uninfected mosquitoes, and consequently to man. He should also be energetically treated with quinine, which rapidly destroys the parasite in the blood. The prophylactic measures are directed towards the protection of the infected person from mosquitoes, the protection also of the non-infected, and the destruction of the larvæ in the water. For this latter purpose kerosene appears to be efficient, if rightly used. A mixture of crude oil and kerosene is very commonly employed, the crude oil being sufficient to thicken the film formed on the surface of the water, but insufficient to form congealed masses. The most suitable time for destroying the larvæ is the winter or the beginning of the spring, when they are fewest in number in the water, and new generations have not yet made their appearance. Approximately 1 ounce of the oil to every 15 square feet of surface is sufficient.

The presence of small fish, such as minnows, in the water is

also effective in destroying larvæ, if there is not too much aquatic vegetation in the stream or ditch, which prevents the minnows from following their prey. The clearing of vegetation from the surface soil plays a most important part in the control of mosquitoes. By cutting close all grass and " bush " in the vicinity of dwellings, the chances of puddles and empty receptacles, which may be breeding-places for larvæ, being overlooked are greatly reduced, and shallow surface pools tend to dry up before the adult larval stage is reached.

Among the odours which are obnoxious to the mosquito are turpentine, menthol, and garlic; among the fumes, tobacco and simple wood smoke; among the gases, the most practical and efficacious destructive agent is sulphurous acid.

In malarial districts an effort should always be made to protect the body against the bites of all proboscidian insects, especially at night, by means of veils, gloves, and mosquito curtains, or by inunction of the skin with oil or liniment containing camphor or eucalyptol. The doors, windows, chimney breasts, and ventilators of dwelling-houses should be protected by wire gauze fittings, with a mesh not larger than twelve strands to the inch, to exclude the entrance of mosquitoes. It should be a rule not to go out of doors after sunset, and suitable clothing should be worn to protect the body from chills. Since Anopheles larvæ are mostly found in clear stagnant pools containing algæ, all such pools should be filled in, drained, or otherwise dealt with, so as to permit of no place remaining where the mosquitoes can deposit their eggs. The same remarks apply to tanks, cisterns, water-butts, refuse tins, etc., which are very frequently the breeding-places of mosquitoes.

In malarious localities in tropical countries a large proportion of the native children harbour the malaria parasite, and the anophelines in native quarters are mostly infected; consequently European settlements should be located at least a quarter of a mile from the natives, and preferably on the windward side of the prevailing winds.

With regard to quinine prophylaxis, the Medical and Sanitary Advisory Committee for Tropical Africa point out that true quinine prophylaxis must be distinguished from relapse prophylaxis, the former being the routine administration of quinine to those who have never suffered from malaria, and never harboured the malarial parasite in their blood, the latter meaning the administra-

tion of quinine for the purpose of preventing relapse after one or more attacks, or its administration to those who already harbour the parasites in their blood, but have shown no signs of malaria. The effect of quinine prophylaxis is that it will in many instances destroy the sporozoites after their first introduction into the blood, and before they enter the red corpuscles. Where it fails to accomplish this destruction, it will to a certain extent prevent the development of the parasites in the body, and consequently the clinical manifestations of malaria. Moreover, its action in all probability depends to some extent upon, and is reinforced by, the ordinary protective agencies, which exist in the human body itself. When, however, the dose of sporozoites is a large one, and when the defensive powers of the body are lowered, no reasonable amount of quinine can be expected to cope with an intense infection. In other words, quinine prophylaxis is a question of dosage, both of infection and of prophylactic. The daily dose of quinine for prophylaxis is usually stated to be 5 grains.

All the old observations regarding malaria can now be accounted for, and their real significance understood. Thus it is an old theory that malarial miasm rises from stagnant water, that malarial outbreaks depend on rainfall, that they can be obliterated by drainage of the soil, and that they are often due to disturbance of the soil—all of these being factors which determine the existence of puddles affording suitable breeding-grounds for Anopheles. Old observers have also noted that malaria is most likely to be contracted about sunset and at night, that the " miasm " did not extend to any great elevation above sea-level, and was not carried by high winds. These facts are all explained by the mosquito theory of infection, for the insects issue forth at sunset, and pursue their search for food through the night, never mounting high in the air, and avoiding windy or stormy nights. So soon as even a moderate breeze springs up the mosquito seeks shelter in bush, house, or corner.

In a pamphlet for official use entitled " Suggestions for the Care of Malaria Patients," 1919, Colonel Sir Ronald Ross and Lieut.-Colonel S. P. James state that clinically there are three chief types of malarial fever commonly met with:—(*a*) A comparatively mild type, in which the febrile paroxysms recur with great regularity every third day, the intervals between the paroxysms being of forty-eight hours' duration—organism, the

benign tertian parasite (*Plasmodium vivax*). (*b*) A severe type, in which the paroxysms may either recur regularly every third day, or sometimes every day, or at irregular times; in this type "pernicious" symptoms are liable to occur—organism, the malignant tertian parasite (*Plasmodium falciparum*). (*c*) A comparatively mild type, in which the paroxysms recur with great regularity every fourth day, the intervals being of seventy-two hours' duration—organism, the quartan parasite (*Plasmodium malariæ*).

A diagnosis of malaria may be arrived at:—(*a*) On the clinical signs and symptoms. If the fever or any other symptom recurs at intervals of approximately forty-eight or seventy-two hours, the disease is almost certainly malaria. If the periodicity is quotidian, the matter is quite uncertain, unless the daily febrile paroxysm comes on before mid-day, at about the same time each day. (*b*) By blood examination. The malarial parasites are more likely to be found in the blood during febrile paroxysms than during remissions or intermissions, and before the administration of quinine than after. A blood film should be taken as follows:—The finger or lobe of the ear, as well as a microscope glass slide and a long straight needle, should all be cleansed, and then thoroughly dried. Prick the finger or lobe of the ear, and as the drop of blood exudes, receive it upon the middle of the slide about an inch from one end. Lay the needle transversely across the slide upon the blood, press the needle firmly on the blood against the slide, and then draw the needle evenly and steadily along the whole length of the slide so that the blood is spread in a flat layer covering the middle part of the slide. Allow the film to dry in the air, and wrap the slide in a piece of paper marked with the necessary identification. Three films should be taken for each case. (*c*) The diagnosis by administration of quinine is only useful for excluding malaria. If a case of fever is not affected by 10-grain doses of quinine given in solution three times on two successive days, it is most probably not a case of malaria. A positive result with quinine does not exclude the disease being one in which the temperature would have fallen without quinine.

The Public Health (Pneumonia, Malaria, Dysentery, etc.) Regulations, 1919.

These Regulations were made by the Local Government Board under the Public Health Act, 1875, Section 130; the Public Health (London) Act, 1891; and the Public Health Act, 1896. Medical

practitioners are required to notify to the Medical Officer of Health cases of malaria, dysentery, trench fever, acute primary pneumonia, and acute influenzal pneumonia. Cases of malaria, dysentery, and trench fever need not be notified by a medical practitioner if to his knowledge the case has been previously notified within a period of six months immediately preceding the date on which he first became aware of the disease in the case. On receipt of a notification, or on becoming aware in any other way of a case of these diseases, the Medical Officer of Health, or an officer of the local authority acting under his instructions, shall make such inquiries and take such steps as are necessary or desirable for investigating the source of infection, for preventing the spread of infection, and for removing conditions favourable to infection. If a medical practitioner is not in attendance, the Medical Officer of Health shall also take such steps as are necessary or desirable for ascertaining the nature of the case. Cases of typhus, relapsing fever, trench fever, and malaria in which there is reason to believe that the infection was contracted in the United Kingdom, must be immediately communicated to the Ministry of Health, also full particulars as to any outbreak of dysentery. If not a County Borough, the like information must be sent to the County Medical Officer of Health. The Medical Officer of Health shall take steps to secure the treatment of cases of malaria, trench fever, or dysentery in a suitable hospital, unless treatment elsewhere can be carried out so as to prevent the spread of the disease.

In cases of malaria, where action is necessary to prevent the spread of infection, the Medical Officer of Health shall take steps to ensure that the patient is (1) supplied with efficient mosquito netting, (2) receives necessary quinine treatment, (3) receives proper advice as to the continuation of quinine treatment in order to prevent relapses, and (4) receives proper advice as to the precautions to be taken to prevent the spread of infection. On the occurrence within a district of two or more cases of malaria in which the infection has, in the opinion of the Medical Officer of Health, been contracted within the district, the local authority may and, if required by the Ministry of Health, shall appoint and pay a medical practitioner approved by the Ministry, who shall (1) make systematic visits to houses where malaria has occurred, or where risk of malaria infection arises, and shall offer to examine suspects, and endeavour to obtain material for microscopic examination; and (2) arrange for the administration of quinine, the use of mosquito netting, and the destruction of mosquitoes.

In any case of dysentery, where it is necessary to prevent the spread of infection, the Medical Officer of Health may by notice in writing require that, until the notice is revoked, (*a*) the person specified in the notice shall discontinue any occupation connected with the preparation or handling of food or drink for human consumption; (*b*) children in the care or charge of any person specified in the notice shall not be sent to school; (*c*) suitable measures to be specified in the notice shall be taken with respect to cleansing, disinfection, disposal of excreta, destruction of flies, and prevention of contamination of

articles of food or drink for human consumption. If a Medical Officer of Health has grounds for suspecting that a person employed in the preparation or handling of food or drink for human consumption is a carrier of dysentery infection, he may give notice to the manager of the business that for the purpose of preventing the spread of the disease he considers it necessary to make a clinical examination of such suspected person. The manager and all other persons concerned shall give the Medical Officer of Health all reasonable assistance in the matter. If from the result of such examination, or of any bacteriological examination, it is the opinion of the Medical Officer of Health that the person is a carrier of dysentery infection, the Medical Officer of Health may give a notice in writing to that effect to prevent during a specified period the employment of the person in any business concerned with the preparation of food or drink for human consumption.

In any case of typhus, relapsing fever, or trench fever of which the Medical Officer of Health becomes aware, he may by notice in writing require that measures be taken to destroy all lice on the person and clothing of every occupant of the building, and of all lice in the building; also for the temporary segregation of inmates of the building and of contacts until completely freed from lice.

The provisions which apply to dysentery (see above) are made to apply with any necessary modifications to cases of enteric fever.

The local authority may provide medical assistance for any person in their district who is suffering from any of the diseases mentioned in the Regulations, if in need of such assistance. On the certificate of the Medical Officer of Health, any person suffering from malaria, dysentery, or trench fever, who cannot be effectively isolated, may be removed to an isolation hospital or other suitable place for the reception of the sick.

Yellow Fever.

This is a specific disease with an incubation period of from two to six days.

Like malaria, yellow fever is propagated by a mosquito, but the species is known as *Stegomyia fasciata*. The Stegomyia breeds chiefly in or near towns, being a domestic mosquito, in contradistinction to the malaria-carrying Anopheles, which loves clean water and jungle streams. The Stegomyia breeds on the surface of cisterns, stagnant pools, or in old pots in neglected backyards. The organism transmitted to man by the bite of the mosquito was discovered by Noguchi, and is known as *Leptospira icteroides*. It is of extreme minuteness, very motile, and can only be seen by dark ground illumination. It is not easily stained, cannot withstand desiccation, and is killed by heating to 55° C. It can pass through the finest bacteriological filters. It can be cultivated in a medium consisting of a mixture

of Ringer's solution, human serum, and neutral agar; and these cultures produce in guinea-pigs a fatal disease characterized by high fever and marked jaundice.

The organism cannot live outside human blood or the body of a Stegomyia, unless cultivated as above described. A mean atmospheric temperature of 75° F., or over, is necessary for the growth of *Leptospira icteroides*. Yellow fever ceases to spread when the air temperature falls below a daily mean of 75°, and stops abruptly as an epidemic when the thermometer falls to 32° F. It undoubtedly exists in the blood of those affected by yellow fever, although only in a state capable of being retransferred to the mosquito during the first six days of the disease, as it is only mosquitoes that have fed on patients during the first six days of the fever that are found to be infective. The organism evidently undergoes some developmental process in the mosquito, as it is found that it is not until twelve days have elapsed after feeding on yellow fever blood that the insect is capable of conveying infection to healthy men. This infective power it retains for the rest of its life.

The preventive measures are very much the same as those for malaria, but quinine is useless as a prophylactic. An anti-icteroid polyvalent serum has been prepared by inoculating cultures of Leptospira containing several strains into horses. This serum, if given shortly after the inoculation of the infection, or before yellow fever appears, entirely prevents the development of the disease. If given when the fever has already started and before the jaundice appears, it prevents development of the jaundice, and the disease runs a very mild course.

By systematic measures for destroying the breeding-places of the mosquito the late General W. C. Gorgas made the work of the construction of the Panama Canal possible.

Malta or Mediterranean Fever.

This is a disease of often very prolonged duration, made up of a series of febrile attacks, with intervals of freedom or comparative freedom from attack. The disease is due to an organism, the *Micrococcus melitensis*, which is found in the spleen, but not in the general circulation, and is therefore of little direct use in diagnosis. The disease is readily conveyed by inoculation, but does not appear to be directly communicable from the sick to the healthy by infected discharges, fomites, or other channels

of infection. The *Micrococci melitensis* are readily agglutinated by the serum of those affected with the disease, and this fact is a great aid in diagnosis. The Commission appointed to investigate the disease in Malta reported that Maltese goats may harbour the micrococcus, and that their milk may be infected with the organism. Goat's milk is the common source of supply in Malta, and it has been established by the work of the Commission that in Malta these animals are the chief, if not the only, means by which the disease is spread. The micrococcus is found in the excreta of goats, and the udders may become infected by infected excretions or soil, but the animals themselves may exhibit no signs of any illness.

The discovery as to the part played by goat's milk in the transmission of the disease was made in 1906, and since that year the use of goat's milk has been prohibited in military and naval barracks in Malta. In the British Army in Malta in 1905 there were 643 admissions to hospital for Malta fever, in 1906 (when the prohibition began to take effect) there were 161 admissions, in 1907 11 admissions, and in 1908 7 admissions. Not only goat's milk, but also cow's milk is now prohibited, as the latter animals have been shown to be liable to contract the disease, and to be as dangerous as goats. The result of the administrative procedure of 1906 has practically been to exterminate Malta fever as a cause of sickness and invaliding in the British Army.

Leprosy.

Although leprosy is almost certainly the result of the introduction into the body in some way, not clearly understood, of a specific organism—the *Bacillus lepræ*—yet some doubt still exists as to whether this disease is ever conveyed by direct or indirect communication between the sick and the healthy. The wives, husbands, or parents of leprous patients, who have elected to be segregated with them on the Island of Molokai—one of the Hawaiian group—do not appear to succumb to the disease in any exceptional proportion as compared with the general population of the islands. Dr. Ashburton Thompson's investigation into the subject supports the view that "the vast majority of instances of apparent spread of leprosy by infection are spoilt by having been observed on areas of recognized endemicity, so that the influence of locality cannot be excluded. . . ." It

seems probable that leprosy enters the system by way of the upper respiratory tract; but it is possible that fleas, etc., may inoculate the disease.

A conference of leper asylum superintendents in Calcutta recently reported that in their opinion leprosy is contagious owing to the escape of *B. lepræ* in the nasal discharges of sufferers, often early cases without visible ulcerations, and to a less extent from open sores. The incubation period is a long one. The disease is not directly hereditary, children being free from infection at birth; but they are specially susceptible to contagion from an early age. There should, therefore, be the earliest possible separation of infants from infected parents, and lepers must be segregated (as in leper settlements) at all periods of their lives. The conference also considered the method of treatment with the salts of fatty acids introduced by Sir Leonard Rogers, I.M.S., was attended with most favourable results, although more research was needed further to improve the treatment.

Beri-beri.

Beri-beri is a disease of wide distribution. It is occasionally to be seen in our docks amongst the crews of ships arriving from the tropics, but is more especially a tropical disease. It occurs generally in limited epidemics, in particular houses, institutions, plantations, mines, etc.; but it may spread over large areas, only attacking, however, limited foci in such areas. The case mortality ranges from 5 to 50 per cent. (Manson). There is no evidence that it is communicable from man to man.

The disease is characterized by difficulties of movement, often attended with some atrophic paralysis (more particularly of the limbs), by loss of sensation, œdema of the legs, and dropsy of the serous cavities. Dilatation of the heart, and consequent shortness of breath on exertion, is a common occurrence. There are several types of the disease; in one the nervous symptoms predominate, in another the respiratory system is most affected, and in a third (œdematous type) the circulatory organs. The disease is essentially a chronic one, and it is said that dampness, overcrowding, and debilitating diseases (such as dysentery) predispose to it. This disease is liable to be mistaken for alcoholic or arsenical neuritis, malarial cachexia, pellagra, scurvy, and pernicious anæmia.

In 1897 Eykman discovered that birds, when fed on polished rice, developed a disease analogous to beri-beri with extensive polyneuritis, and that this disease was not induced when the birds were fed with unpolished rice. In 1906 Eykman showed that the aqueous extract of rice polishings cured polyneuritis, and that the active constituent in the extract was dialyzable and soluble in alcohol (*vide* "Vitamines," p. 310).

Fraser and Stanton are of opinion that beri-beri is associated with the consumption of white rice as the staple food, such rice having lost something in the process of milling which is essential for the nutrition of nervous tissue. This substance exists in adequate amount in the original grain, and in superabundant quantity in the polishings from white rice. The prevention of the disease will be achieved by substituting for ordinary white milled rice an unshelled rice in which the polishing process has been omitted,[1] or by the addition to a white rice diet of articles rich in those substances in which such rice is deficient. The polishings contain a nitrogenous substance which is essential in the metabolism of the nervous system. This "antineuritic" substance appears to be a pyrimidine base, but its exact nature is not known. It may act as an activator or catalyst in metabolism, thereby rendering possible the assimilation of certain nutrients, possibly phosphorus compounds. Beri-beri amongst people who are not rice eaters is probably due to the absence from the food of this same antineuritic substance. Norwegian ship crews, who are now fed on wheaten bread, tinned meat, and cooked fish, occasionally develop the disease, whereas when the diet consisted of salt meat, peas, and biscuits made with rye flour, they did not do so. A liberal and judicious diet is the best preventative.

Beri-beri is now regarded as essentially a "deficiency" disease like scurvy. The disease arises when the diet is deficient in anti-beri-beri (water-soluble B) vitamine. This is a nitrogenous substance, but not a protein. It does not contain phosphorus. It is soluble in water and alcohol or dilute acids. It is destroyed on heating to 130° C., but not at a temperature of 100° C., nor by dilute acids, though sterilization of foods undoubtedly destroys it. Tinned foods, owing to the heat employed

[1] The phosphorus content of rice serves to indicate the extent to which it has been polished. P_2O_5 amounting to 0·4 or 0·45 per cent. would appear to indicate safe rice, judging by experiments on fowls.

in their sterilization, are almost entirely deficient in anti-beri-beri vitamine. Yeast is a substance which is, perhaps, the richest in this vitamine. Egg yolk, brain, liver, kidneys, sweetbread, oatmeal, haricot beans, and peas are all fairly rich in it. Milk and fresh meat contain only small amounts (Willcox).

Pellagra.

This is an endemic disease occurring in Europe and other parts of the world—Egypt, South America, South Africa. It occurs amongst the poorer classes in rural districts, and has a seasonal prevalence in spring and autumn. The disease is characterized by alterations in the skin, cachexia, and is often fatal. It was formerly thought to be due to the consumption of inferior or diseased maize, but it may occur amongst people whose staple diet is not maize, and even in places where maize is rarely eaten. There is no evidence pointing to an infective origin of the disease. It seems probable that pellagra is due to the continued consumption of a protein of low value from the point of view of amino-acids. Thus the use of maize which is badly cooked, or of other vegetable products which are never varied, as the principal or only sources of proteins, may originate the disease. The addition of casein or animal proteins to the diet seems often to effect a prompt cure. Pellagra is, therefore, a deficiency disease, but the deficiency is in a protein of proper quality for the needs of the body. It is not a vitamine deficiency.

Dengue.

This specific febrile disease is peculiar to warm climates, and is characterized by severe muscular and articular pains, and sometimes by a cutaneous eruption. It is especially prevalent in the dry, hot seasons of very warm climates, so that a high temperature is doubtless one factor which determines incidence. One attack is generally protective. The disease is spread by *Stegomyia fasciata*, and possibly other mosquitoes, but the causative organism is unknown. It is probably ultra-microscopic and filterable.

Filariasis.

The parent filariæ (*Filaria Bancrofti*) are long, hair-like, transparent nematode worms, three or four inches in length. The two sexes live together, often coiled about each other, and are found in the lymphatics of affected men, in lymphatic varices,

and sometimes in the larger lymphatic vessels, and in lymphatic glands. The diseases which the adult filariæ give rise to are of wide distribution in the tropical and sub-tropical world, and are endemic chyluria, various forms of lymphatic varix, probably tropical *elephantiasis arabum*, and other obscure tropical affections. The worms cause obstruction to the flow of lymph in the implicated vessels, and the lymphatic areas drained by these vessels are cut off from the general circulation. There then follows a rise of pressure in the occluded lymphatics, with consequent varicosity or lymphatic œdema, or a combination of the two.

After fecundation of the female nematodes by the males new generations of embryo filariæ are poured into the lymph. These eventually pass into the general blood circulation by way of the thoracic duct and the left subclavian vein. These embryos (*Filaria nocturna*) are minute, transparent, worm-like organisms, about $\frac{1}{80}$ inch in length, each enclosed in a delicate sheath. The filariæ are only found in the peripheral circulation during the hours of night. During the day they retire to the larger arteries and to the vessels of the lungs (Manson). Should the females of certain species of mosquito (*Culex fatigans*) feed on the blood of a filariæ-infected man—which they do almost exclusively at night time—the filariæ enter the stomach of the mosquito. Here the filariæ escape from their enclosing sheaths, and swim freely in the blood. They then migrate from the stomach and enter the thoracic muscles of the mosquito, where they develop enormously—growing to $\frac{1}{16}$ inch in length—and acquire a mouth, an alimentary canal, and a trilobed tail. They next quit the thorax, and enter the head, where they coil themselves up close to the base of the proboscis, and await an opportunity to enter a warm-blooded vertebrate host, when the mosquito feeds on such, and so complete the cycle of their existence. In man the periodic nocturnal migrations of the filariæ from the large vessels to the peripheral circulation is evidently an adaptation to the nocturnal habits of the mosquito, so as to secure the change of host to the mosquito necessary to complete the cycle of existence and the propagation of the species.

Sleeping Sickness.

The Report of the Commission on Sleeping Sickness in Uganda shows that this disease is caused by *Trypanosoma Ugandiense*. This organism (flagellated hæmatozoon) is a minute, colourless,

transparent, active vermicule, provided with a long flagellum at its anterior extremity, which is found free and active in the liquor sanguinis of those affected with the disease. It is never seen in the red corpuscles. The trypanosomes are conveyed from the sick to the healthy by the tsetse fly, and not by other biting flies. Reproduction of the trypanosomes is effected in the alimentary canal of the tsetse fly by longitudinal division. The trypanosomes are sexless.

The tsetse fly is indigenous to the equatorial regions of Africa, which are known as "fly-belts"—*i.e.*, those regions where the fly is found at one or another season of the year. One species (*Glossina palpalis*) is chiefly concerned in the transmission of the disease known as "sleeping sickness," whilst another species (*Glossina morsitans*), although now believed to act occasionally as a carrier of sleeping sickness, is best known as the cause of spread of the epizoötic South African cattle disease "ngana," which is terribly fatal to horses and cattle.

Tsetse flies are dull-coloured brown insects, from $\frac{1}{4}$ to $\frac{2}{5}$ inch in length. When at rest the wings are closed flat one over the other like scissors, and this is a character which serves to distinguish glossina from all other blood-sucking flies. Tsetse flies do not lay eggs, but give birth to a yellow larva, which burrows into a hole to undergo its developmental changes. The fly is chiefly found where there is water—namely, on the banks of rivers and lakes, where they abound in the scrub and jungle.

Trypanosomes adhering to the proboscis of this fly are injected by the bite under the skin, and are thence transferred by the lymphatic vessels to the lymphatic glands, which become swollen. Very few symptoms of illness are caused so long as the trypanosomes are confined to the glands, and it is reported that at one time in the affected parts of Uganda from 50 to 75 per cent. of the native inhabitants had enlarged glands from this cause, but were able to carry on their ordinary avocations. After a variable period of little or no illness, the trypanosomes spread through the blood to the membranes of the brain and spinal cord, when symptoms of lethargy, intense drowsiness, emaciation, tremors, and exhaustion ensue, which invariably end fatally.

In the prevention of sleeping sickness it is important to recognize affected individuals in the early stages of illness. This can be done by withdrawing with a hypodermic syringe some fluid from the enlarged glands, when the trypanosomes, if present,

can be readily recognized. An attempt should be made to isolate affected individuals in a camp, but this is clearly impossible if large numbers are affected. There is no hope of exterminating the fly. The removal of affected populations from the chief fly areas to others less affected has been tried, but without success, as it has been found that the flies of the depopulated areas do not free themselves from trypanosome infection, even after a lapse of two years. It seems certain now that the trypanosomes of sleeping sickness are capable of being harboured in other vertebrate hosts as well as in men.

Ankylostomiasis.

This is an endemic anæmia, which is very prevalent in the tropics, but is generally known in Europe as "miners' anæmia." It is caused by a parasitic nematode worm, the *Ankylostoma duodenale*, whose habitat, as its name implies, is the small intestine of man. The worms attach themselves to the mucous membrane, and from the blood obtain their nourishment. The anæmia produced is generally ascribed to the continued small losses of blood, but another theory seeks to explain the anæmia as the direct result of the absorption by the blood of toxic substances derived from the parasite. The worms measure from 6 to 15 mm. in length, and sexual intercourse between males and females takes place in the intestine. The female produces an enormous number of fertilized eggs, which pass out in the fæces of the host. The embryos pass their lives in mud, earth, or muddy water, and may be transferred to man either by means of the water drunk, or by soiled food or hands, when they pass at once into the digestive tract; or they enter the skin, usually of the feet or legs, gaining access to the lymphatic vessels, and later to the subcutaneous veins; having entered the circulation they reach the œsophagus, stomach, and duodenum, where they become sexually mature.

The disease occurs in all tropical and sub-tropical countries, and is known in Southern Europe and Belgium. It has recently been introduced into deep Cornish mines in England, where the depth of the mine ensures a relatively high temperature of the underground workings. It is undoubtedly spread in mines by miners defæcating underground on to the earth, no proper system of fæcal collection and removal being adopted, or fully availed of by the men if provided. A diagnosis is best made by an

examination of the fæces for the ova of the worm, which have a regular oval form, with smooth transparent shell, through which two or four light grey yolk segments can be seen. The encapsuled larvæ of the worm may live in water for a year or more, and they are very resistant to most disinfectants, but creosote kills the larvæ quickly, and a solution of the sulphate of iron is also valuable.

Fortunately the large majority of British coal-mines are too cold for this worm, which leads to a condition which very seriously incapacitates the infected miners.

Weil's Disease.

This disease is characterized by jaundice, pyrexia, and hæmorrhages. It is apparently infectious, as cases occur in groups and even in widespread epidemics in the United States, India, Africa, and Japan. In the British Isles the epidemic form is rare, but the family type of infectious jaundice is well known. In 1915, it was discovered that a spirochæte—*Leptospira icterohæmorrhagiæ*—is the cause of Weil's disease, and that the blood of patients recovering from the disease contains protective substances against this spirochæte. The experiments made with normal people and patients suffering from catarrhal jaundice produce no such results. In the early stages the spirochætes are in the blood stream, but as the illness progresses they disappear. The disease appears to start as a gastro-intestinal infection, most marked in the duodenum, and it is probable that the epidemic catarrhal jaundice (with no pyrexia or spleen enlargement) is a benign form of such infective jaundice. The infection is almost entirely conveyed through the alimentary tract by food (probably contaminated by dust or flies, and to a less extent by water). There is a probability that it is sometimes air-borne and may even occur through the skin. Infection from man to man is rare.

The natural reservoir of the Leptospira is the rat, in which animal it is found in the fæces, urine, and kidneys, but not in the blood. The disease was probably at one time a rat epizoötic, but now these animals have acquired immunity. Foulerton has found 4 per cent. of London sewer rats examined infected with *Leptospira icterohæmorrhagiæ*. It seems probable that man acquires the disease by consuming rat-contaminated food.

Epizoötic Diseases.

We have in Great Britain the following diseases which are unquestionably communicable from animals to man: anthrax, tuberculosis, rabies, foot and mouth disease, glanders, variola, mange (horse, dog, cat, etc.), ringworm (horse, calf, cat, etc.).

Anthrax.

This specific disease affects cattle most frequently, but all animals are capable of being infected. The infection generally enters the body through the alimentary tract, but it may be introduced through the respiratory tract, and also through the skin by inoculation (by the stings of insects, through abrasions, etc.). When the soil becomes infected, as by discharges from animals, the disease may spread rapidly and extensively through herds. Pasteur and others have held, on experimental evidence, that when animals dead of the disease are superficially buried, earth worms may be instrumental in conveying the specific organism to the surface. The grass may become extensively contaminated by discharges from sick animals, and the specific organism, in the form of spores, can persist for considerable periods in decomposing animal and vegetable matter. Animals feeding on infected pastures may become inoculated through wounds inflicted on the buccal mucous membrane and the tongue by silicious grasses, probably, too, by swallowing the spores with their food. The disease is most prevalent on warm, loose, moist soils, rich in organic matter, especially in swampy, boggy districts, and during the summer months. Animals may also be infected by infectious refuse from factories where hides, etc., are dealt with, and from the use of certain manures and imported foodstuffs.

Man may be infected from the living animal, but he is generally infected during the process of killing and skinning diseased animals, and possibly by eating the flesh. In this country the sorting and handling of wools, hides, or hair (especially horsehair from Russia and China) imported from abroad is most frequently responsible for the disease, hence the popular name of "wool-sorter's disease." It appears that the blood-stained wool or hair are the actual carriers of the germs of anthrax; hence the amount of blood-staining is a rough measure of the danger to the operatives. Man is infected either by direct inoculation

of a wound or abrasion on the face and hands, arms, and legs, which give rise to the malignant pustule, or by inhalation of dust containing spores into the mouth or lungs, when general infection of the system follows, usually proving fatal in the course of a very few days.

Cases of anthrax in man have been shown to be due to the use of shaving-brushes which had been infected with anthrax spores. The bristles of these brushes were found to be largely composed of mixed hair of Chinese origin, chiefly goat, horse, pig, and human. This imported hair had escaped the disinfection required by Home Office Regulations. The skin of the face or neck became inoculated during shaving, after the parts had been lathered with the shaving-brush, no doubt through skin abrasions.

The symptoms of general infection are usually obscure, and appear to depend upon the organ with which the virus first comes in contact; if the dust is swallowed, the stomach and bowels are chiefly affected; if inhaled, the lungs. Bacilli are found in the serum of the pustules, and in the blood after death.

Infection through the alimentary tract is rare. In man it is much more common for the disease to start in the respiratory system, the lesions being found in the trachea or bronchi, and spreading to the bronchial and other thoracic glands, and finally to the lungs. In the lung cases many bacilli may be found in the local lesions in the chest, but few are found in the other organs or in the blood, until just before death. Bacilli are rarely found in the secretions.

The disease may assume the following types, each of which is also met with in man:

1. "Apoplectic": Symptoms of cerebral apoplexy appear; the animal is taken suddenly ill, staggers and falls, and dies in convulsions in from a few minutes to one hour at most. This is the most usual form in sheep and goats.

2. A condition of excited restlessness is followed by convulsions, stupor, and death, as if from apoplexy. The symptoms last from two to twenty-four hours in this form, which is the most usual in cattle.

3. "Anthrax fever": This is the most common form, lasting from twenty-four hours to seven days. High fever and frequent colic are followed by symptoms similar to those of the last type, but the grave symptoms are intermittent, and their duration is more prolonged.

4. "Carbuncular disease": Characterized by circumscribed cutaneous swellings, at first hard, hot and painful, and later becoming cold, painless, and with a tendency to slough, but not to suppurate; œdematous swellings of the skin; similar swellings on the mucous membrane of the mouth, pharynx, larynx, and rectum; irregular fever;[1] dyspnœa, difficulty in swallowing; muscular spasms. This form generally lasts from three to seven days, and is very fatal, the case-mortality amounting to some 25 per cent.

The post-mortem diagnosis depends upon: (1) The discovery of the bacillus, and the results of its inoculation into mice; (2) hæmorrhages of variable size, often evident in all the organs and in the subserous, submucous, and subcutaneous tissues, and serious infiltration and congestion of organs generally; (3) swelling of the spleen to from two to five times its normal size: the liver, kidneys, and lymphatic glands are also enlarged, though to a less degree; (4) a tar-like condition of the blood. The bodies are often well nourished; there is an absence of rigor mortis; rapid decomposition sets in, and where there is considerable œdema there may be wide areas of necrosed skin.

In this disease, as in some others, such as chicken cholera, rabies, and swine fever, the virus can be attenuated by the various methods mentioned on pp. 419 and 420. When cultivated at 42° C., the bacilli of anthrax produce no spores, and the intensity of their virulence decreases day by day. This attenuated virus (or it may be the waste products of its metabolism), when inoculated into susceptible animals, inhibits the growth of the specific microbes when introduced into the body, and is so found to confer immunity for a time from the disease in its virulent form. The same result can be attained when the bacillus from one species of animal is passed through a different species. If the bacilli of sheep or cattle are inoculated into guinea-pigs, the

[1] The following are the symptoms of fever in cattle: The temperature (*per rectum*) is generally about 41° to 42° C.; the external temperature of the body is unequally distributed; the hair stands on end and loses gloss; feeding and rumination are suspended; great depression; eyes dull and congested; tongue protruded; often diarrhœa; short panting respirations; frequent small pulse (60 to 120 per minute); nostrils dry or covered with foam; in cows, secretion of milk is diminished and the teats are hot; rigors.

In horses the symptoms are similar; the temperature is generally about 39·5° to 41·5° C., and the pulse from 80 to 100 per minute.

organisms taken from the guinea-pig are attenuated for sheep or cattle, and confer immunity from subsequent attack.

Pasteur used two vaccines: Vaccine I. grown at 42° C. for twenty-four days, and Vaccine II. grown at 42° C. for twelve days, and therefore less attenuated than Vaccine I. The method as used for sheep, cattle, and horses is as follows:—The animal is inoculated with Vaccine I. (5 drops for sheep, 10 for cattle and horses), and after twelve days with Vaccine II. Fourteen days later an ordinary virulent culture can be injected without ill effect, and the animal remains immune for a year or more in many cases.

Quite recently mice have been rendered immune against anthrax virus by injection of an albumose (a proteid body) isolated from cultures of the anthrax bacilli, of whose metabolism it is no doubt a waste product (Hankin). The quantity of anthrax albumose necessary to produce immunity is extremely minute.

Sclavo's anti-anthrax serum has been used in this country during the past few years with encouraging results.

Sanitary Precautions.—The opening of bales and the sorting of hides should be carried out in special well-ventilated rooms only by experienced workmen, and by those whose hands and arms are quite free from any abrasion. Handling should be reduced to a minimum, and any suspected wool or hides should be well moistened before handling; but a safer procedure would be to disinfect all bales by steam under pressure prior to handling, although this is liable to damage them.

Anthrax is, however, the most protean in its manifestations of all trade diseases and the most difficult to control. Disinfection of horsehair by steam would not at first sight seem difficult, but experiments have hitherto shown that penetration into hydraulically pressed bales is impossible, and that even when they are not hydraulically pressed the environment of the spores, embedded as they are in grease and dirt, offers a great obstacle to successful disinfection.

However, adequate steam disinfection, provided the bales are opened and the horsehair spread out (in which operation, of course, danger is incurred), will give a certain guarantee of the destruction of the anthrax contagion. The soakage of hides for twenty-four hours in a fluid containing 1 per cent. of formic acid and 0·62 per cent. of mercuric chloride, and then transferring them to the ordinary brine pit, is also recommended for hides.

But it is now officially recognized that complete disinfection of highly infected material can be obtained without damaging the raw material by the following process:—The material is first submitted to the action of a warm solution of soap in water containing a little alkali, followed by squeezing through rollers. The purpose and effect is to cause disintegration of blood clots and the removal of all protection from the spores, and to bring the latter into a condition in which they are susceptible to the action of disinfectants. The material is then submitted to the action of a warm solution (102° F.) of $2\frac{1}{2}$ per cent. formaldehyde in water for fifteen minutes, and then again squeezed through rollers. Most of the spores are destroyed at this stage. All the surviving spores, except in special circumstances, are killed by a current of hot air reaching 160° F. The material is then allowed to stand for a short period in order to further ensure the destruction of any surviving spores. The last two stages are largely in the nature of a safety factor. The method lends itself to continuous and rapid working on a large commercial scale without damage to the articles disinfected. The material can be fed into a machine and not again handled until it has emerged clean, dry, and disinfected, and the cost does not exceed three farthings per pound. The time occupied by the actual treatment is about $1\frac{1}{2}$ hours.

Mechanical downward exhausts, actuated by a fan, should be provided beneath the sorting benches to draw away the dust, which should be collected in a washer or condenser. The water from the washer should be well boiled before it is emptied down a drain. If the dust is collected dry, it must be carefully gathered together and burnt. The dust must not be allowed to reach the external atmosphere, or it may be blown long distances and infect grazing cattle. It is during the "carding" process, when the wool is torn apart by high-speed machinery which shoots particles into the air, that most cases of anthrax infection occur.

The premises must be kept clean; the floor of the sorting room should be impermeable, and washed down with disinfectant solution daily.

There must be adequate provision of air space and ventilation.

Dr. Legge, H.M. Medical Inspector of Factories, suggests the following precautions for the prevention of the disease:—

1. That all workers should wear overalls.

2. That no one with any cut, sore, or abrasion of the skin

should be allowed to work unless he can be absolutely protected from contamination.

3. That all workers should wash themselves frequently, and especially before taking food.

4. That all cases of illness, especially if connected with any swelling or boil, should be immediately intimated to the manager, in order that the disease may be attacked in its earliest stages, and that other workers similarly exposed may be warned of their danger.

5. That the bales should be immediately immersed in water, and that no handling of the raw material be permitted except in the wet state. This will prevent dust, and the risk of contagion then will only be possible through an abrasion of the skin. No reliance can be placed on protection from dust by the use of fans, respirators, or currents of air. The germ must be killed.

6. That the hair should be boiled—say for thirty minutes—in order to cleanse it, and soften the agglutinated discharges which may contain the germs, and that afterwards steam should be applied for the same time at a pressure of 1·5 atmospheres. If, however, it be desired to effectually disinfect by boiling, without continuing it so long as to destroy the material, it could be accomplished by using a 2 per cent. solution of potassium permanganate, and afterwards bleaching with a 3 per cent. solution of sulphurous acid.

7. That all dust and residue be frequently collected and carefully burned.

By the Anthrax Order (1899) of the Board of Agriculture, dung and other litter from the place of outbreak are to be burnt, or disinfected and buried to the satisfaction of the inspector. Carcases must either be buried in lime, with the skin on, as soon as possible at a suitable place to which animals will not have access, and at a depth of not less than 6 feet below the surface; or they must be destroyed by exposure to a high temperature, or by chemical agents in a horse-slaughterer's or knacker's yard, or other place approved for the purpose by the Board. A carcase of a diseased or suspected animal shall not be buried or destroyed otherwise than by the local authority, nor be removed from the farm or premises upon which the animal died or was slaughtered, except for the purpose of being buried or destroyed. Before a carcase is removed for burial or destruction, all the natural openings must be plugged with tow or other suitable material

saturated with a disinfectant. In no case shall the skin of the carcase be cut, nor shall anything be done to cause the effusion of blood, except by a veterinary inspector and for the purpose of microscopical investigation. Disinfection in cases of anthrax shall be performed by the local authority at their own expense, and shall consist in thorough sprinkling with freshly burnt lime or other suitable disinfectant, and subsequent washing with limewash containing in each gallon 4 ounces of chloride of lime, or ½ pint of commercial carbolic acid. In practice it is found that infected hides and skins may be disinfected without injury by the Schattenfroh method, which consists of immersion in a solution of 2 per cent. HCl and 8 per cent. NaCl. The measures applicable to infected fields are left to the discretion of the local authority or their inspector.

Under the Factory and Workshop Act (1901), all cases of anthrax occurring in factories and workshops must be notified to the chief inspector of factories.

Tuberculosis in the Lower Animals.

The disease is characterized by nodular deposits (tubercles), frequently translucent and hard, and about the size of a millet grain, which cannot be shelled out from the surrounding tissue

The disease is most frequently found in cattle, pigs, and birds, but occasionally in all warm-blooded animals. Among adult cattle the proportion affected is not less than 30 per cent. in this country.

The symptoms in cattle commence insidiously, and are as follows: A dry, short, jerky cough; increased sensibility of the chest walls; at a later stage, spasmodic paroxysms of cough, especially in the early morning; percussion sounds dull over circumscribed areas; dyspnœa (shown by the extended position of the head and neck); diminished secretion of milk; flatulence; intermittent colic, with alternating diarrhœa and constipation; hæmaturia; enlargement of glands; irregular fever; excessive emaciation; weakness; often peritonitis, and swellings of bones and joints. Animals frequently come on heat and remain so for a long time, cows mounting their fellows, but rarely becoming fecundated by bulls; and pregnant cows frequently abort. Brain excitement, convulsions, paralysis, staggers, and sudden collapse often supervene during the last stages. Tuberculosis of the udders is characterized by a diffuse, painless, and compara-

tively firm swelling, usually of one quarter of the udder (one of the posterior quarters as a rule); the milk at first is normal, then becomes thin and watery, with flakes, and generally, though not always, the specific bacilli are present. The pudic glands are also enlarged. The condition differs from ordinary mammitis or garget, by the gradual increase in the size of the swelling and in the comparative absence of pain on pressure.

The post-mortem diagnosis is chiefly made from the lungs and serous membranes, which are found to be studded with the tubercle nodules. In the lungs the nodules frequently form grape-like clusters which project from the pleural surfaces. The lymphatic glands of the body generally are often enlarged and affected with tubercles.

According to the experience in the public abattoirs of Germany, the different organs are affected in the following order of frequency: Lungs 75 per cent. of all the cases, visceral pleura 55 per cent., peritoneum 48 per cent., costal pleura 47 per cent., bronchial and mediastinal glands 29 per cent., liver 28 per cent., spleen 19 per cent.; no other part of the body is affected in more than 10 per cent. of the cases, and the udder is affected in only 1 per cent.

In pigs the starting point of the infection is generally in the intestines, as the infection is almost invariably swallowed; in cats it is chiefly in the lungs. The disease is sometimes found in goats, and therefore the popular belief that goat's milk is safe is not warranted. In birds the leading symptoms are: Emaciation, pallor of the mucous membranes of the eyes and mouth, loss of appetite, vomiting, diarrhœa, swellings of joints, tumours, and sometimes ulcers.

In applying the tuberculin test for diagnostic purposes, the animal is first allowed to become cool and quiet; then the temperature is taken *per rectum*, the thermometer being allowed to remain in for five minutes. The normal temperature of bovine animals ranges from 38° to 39° C. It is convenient to inject the tuberculin (35 to 45 minims according to the age and size of the animal) into the neck or shoulder, late in the evening, so that the observation of the reaction temperature may be made early next day. The animal must not be regarded as certainly tuberculous unless the temperature at some time during the following day shows a rise of at least 1·2° C. above that of overnight. The rise may be as much as from 2° to 3° C. Animals suffering from

advanced tuberculosis often fail to show a marked temperature reaction, or, if they are already feverish (*i.e.*, temperature above 39° C.), the reaction may not be noticeable. The test must not be repeated until at least a month has expired, as the animal will often not react again in a less period. This fact, it has been suggested, opens the door to fraud, as a dishonest salesman could inject his animals a few days prior to sale, and then sell them as tuberculosis free. Those animals which react should be isolated, and fattened for food, if the disease is in the initial stage and strictly localized to the lungs.

Rabies.

In this disease the virus is contained in the saliva of rabid animals, such as dogs, wolves, horses, bovines, cats, pigs, sheep, goats, and even birds. The disease is spread by inoculation into the skin through the bite of a rabid animal.

The incubation period in dogs is from three to six weeks on an average, with a minimum of a few days and a maximum of several months. The symptoms of canine rabies assume two forms—*i.e.*, the "furious madness," which is the more frequent, and the "dumb madness." The symptoms in the furious form follow each other in three stages: (1) The melancholy, (2) the irritative, and (3) the paralytic. *Stage* 1 generally lasts from twelve to forty-eight hours, and is marked by capricious appetite, the animal being sullen, nervous, excited, irritable, and distrustful; it bites at everything, and often swallows foreign bodies. There is sometimes abnormal itching at the site of the bite. *Stage* 2 lasts three or four days, and is characterized by attacks of fury (which may continue for some hours) and convulsions, with remissions. The animal is very irritable, and often tries to run away; it shows an excessive morbid desire to snap, and later to bite, often with such force as to break its teeth. The animal does not try to bite human beings unless approached. Paralysis of the vocal cords often causes a change in voice. Hallucinations are more prominent than mania. In *Stage* 3 the animal is much emaciated, the hair stands on end and is rough, the eyes are sunken and glassy, and the power of swallowing is lost owing to paralysis of the muscles of deglutition; paralysis of the lower jaw then supervenes, and the jaw drops down, the tongue hanging out; the hind quarters next become paralyzed. The whole stage is attended by paroxysms of excitement, which

grow less and less frequent, until the animal dies between the fifth and tenth day.

Dumb madness differs mainly in the absence, or very short duration, of stage 2.

In man there is premonitory pain in the cicatrized wound from the bite, general malaise, swelling of the neighbouring lymphatic glands, and aversion to fluids. In the second stage reflex spasms, delirium, and mania supervene, the spasm affecting chiefly the throat when attempts are made at swallowing, and being excited even by the sight of water or the thought of drinking; there is also much anxiety, uneasiness, and thirst, and the patient slavers, because of the inability to swallow the saliva. The third stage is characterized by paralysis and spasms, and death supervenes in from two to four days.

Whilst in the man the usual period of incubation after the infliction of a bite by a rabid dog is somewhere about six weeks, it may be as short as six days or as long as two years (Horsley). In 1903 Negri described certain rounded or angular bodies as occurring in the nervous system of animals dying from rabies. There is a general disposition to regard these as specific, but their true nature is not yet conclusively determined, and their etiological significance remains *sub judice*. The rabid virus is chiefly contained in the nervous centres, and it is presumed that the disease only shows itself when these centres are attacked by the virus. This view explains the unequal length of the incubation period in different cases, the incubation period being governed by the time taken by the virus to travel from the point of inoculation up to the central nervous system, and for its development therein. If the virus travels up the nerves the incubation is long, but if conveyed in the blood stream the incubation may be very short.

Horsley gives the death-rate among persons bitten by indubitably rabid dogs as on the average about 15 per cent.; that is to say, about 85 per cent. of the persons bitten are insusceptible, or, at least, escape the action of the virus, for rabies once developed is almost invariably fatal.

Pasteur elaborated a system of treatment by protective inoculations, which has proved of great value. Shortly, it may be described as follows: The virus from the central nervous system of a rabid dog or wolf is inoculated subdurally into a rabbit; a second rabbit is similarly inoculated from the first, a

third from the second, and so on until a virus of maximum intensity is obtained—killing a rabbit in seven days. The spinal cord of a rabbit thus killed by this virus is submitted to a drying process (by calcium chloride), at a temperature of 25° C., for a certain number of days (one to fourteen). By this means the virulence of the virus is diminished and eventually destroyed by drying for fourteen days. The person undergoing the treatment is inoculated first with an emulsion of a cord, which has been dried for fourteen days; on succeeding days he is inoculated with cords which have been dried for thirteen, twelve, eleven, etc., days; and finally with a cord which has been dried for only one day, and is therefore highly virulent. Persons who have been bitten by indubitably rabid animals, and have submitted themselves to the Pasteur treatment within a few days of the infliction of the bite, have almost invariably escaped. The death-rate, instead of 15 per cent. in the unprotected, is only 1·36 per cent. in the protected. During the ten years 1886-95 the mortality in protected persons was only 0·48 per cent. (Muir and Ritchie). For the more dangerous wounds the number of inoculations is greater, and the use of the recent cords is more rapidly brought into operation. This is the "intensive" treatment, which is used in severe cases, as bites on naked parts and wolf bites.

In this country rabies is spread by infected dogs. Where muzzling regulations and the slaughter of stray dogs have been enforced, the disease is rapidly exterminated.

The diagnosis of the earlier symptoms largely depends upon whether proof is forthcoming of the animal or man having been bitten by a rabid animal. The post-mortem changes in canine rabies are neither constant nor specific; but the following diagnostic appearances may be mentioned—emaciation, dark blood, hyperæmia of mucous membranes and of many of the internal organs, the frequent presence of foreign bodies in the pharynx and œsophagus or the stomach, which often contains such articles as straw, hair, feathers, string, wood, or pebbles, but very little or no food. Frequently small hæmorrhages are seen on the surface of the gastric and buccal mucous membrane, and the intestines are generally found to be empty.

When a person is bitten by a dog in an area in which rabies is suspected, the wound should be treated as soon as possible with undiluted carbolic acid or Izal, or other disinfectant. The disinfectant should be allowed to come into contact with all parts

of the wound, and should then be washed out with water. If the diagnosis of rabies in the dog is confirmed, or notice is received from the Ministry of Health that the case should be regarded as one of rabies for purposes of treatment, the person bitten should be urged to undergo specific antirabic treatment as soon as possible. This can be given either in London or in Plymouth with material specially supplied by the Pasteur Institute in Paris. As soon as information reaches the Medical Officer of Health that a person in his district has been bitten by a dog suspected of being rabid, the facts of the case should be reported to the Ministry of Health—namely, name, age, and address; date when bitten; severity of bite and part bitten; name and address of owner of dog; whether rabies in the dog has been diagnosed locally. The Ministry of Health will inform the Medical Officer of Health if the Veterinary Officers of the Board of Agriculture advise that the dog is to be regarded as rabid. The Medical Officer of Health should await instructions from the Ministry of Health before sending a patient away for treatment. In the case of persons who cannot afford to pay the expense of living in London or Plymouth for the three weeks necessary for the completion of the course of treatment, the money required may be provided by the Sanitary Authority of the district.

Foot and Mouth Disease.

Foot and mouth disease is peculiar to ungulates, and therefore occurs chiefly in cattle, sheep, pigs, and goats; but all wild ruminants are liable to it. The disease is rarely fatal.

The symptoms in cattle are: Vesicles and ulcers on the oral mucous membrane, and on the skin of the coronet and of the interdigital space (sheep, goats, and pigs are usually affected only on the feet). The small yellowish-white vesicles on the gums, tongue, buccal mucous membrane, and lips gradually increase in size, until they become as large as a five-shilling piece, when the vesicles burst, leaving ulcers. There is much salivation, and rapid and great emaciation. The milk is colostrum-like in appearance and taste; and in milch cows the exanthem often spreads, by the act of milking, to the udders and teats.

There is often violent inflammation of the udder, with sero-sanguineous discharge; sometimes ulcers form on the pharyngeal mucous membrane, and there is dyspnœa and nasal and bronchial

catarrh. Occasionally the vesicles form on the skin at the base of the horns, also on the vulva and vagina, and on the general surface of the skin.

As regards the feet, there is first a painful swelling of the coronet, especially between the toes and towards the plantar cushions; then lameness results. Erysipelatous inflammation sometimes supervenes, and later on ulcers and abscesses; as a result, the hoofs may be shed. The general constitutional symptoms are those of pyæmia.

In the malignant type, symptoms supervene resembling apoplexy, and the animal dies suddenly from paralysis of the heart, due to the development of toxins.

The disease may be transmitted to man through milk, butter, and cheese, or is inoculated through wounds in the hands and arms. The symptoms are: Fever; disturbance of digestion; vesicles on the face (lips and ears), the fingers, the arms, the female breasts, and the mucous membrane of the mouth, pharynx, and conjunctiva; abdominal pains; and vomiting. Occasionally death supervenes in young persons. The disease is not conveyed by eating flesh. A few outbreaks have been reported among infants fed upon infected cow's milk.

Glanders.

Glanders and farcy are now recognized as different manifestations of the same disease. It is essentially an equine disease, affecting horses, donkeys, and mules; but it may be transmitted from horses to many other animals, including man, by direct inoculation. In some years the disease causes a considerable mortality in this country among horses. It may be transmitted by ingestion, inhalation, and inoculation.

The symptoms may be those of either acute or chronic glanders. Acute glanders is a very rapidly progressive specific infective disease. The prominent symptoms are: High temperature; rigors; muco-purulent nasal discharge, which later becomes sanguineous, the visible mucous membrane being covered with small nodules and ulcers, which are frequently confluent and covered with diphtheritic-like sloughing masses; dyspnœa; and roaring inspirations. There are also œdematous swellings, nodules, and ulcers of the skin; inflammation of the lymphatic vessels (especially in the neighbourhood of the head); swelling and suppuration of the lymphatic glands; difficult deglutition,

diarrhœa, and rapid emaciation. This form is invariably fatal in from three to fourteen days.

Chronic glanders has an insidious origin. The symptoms are: Chronic nasal catarrh, with discharges, which later become less sticky and yellow, and temporarily sanious, these hæmorrhages from the small ulcerous erosions being frequently the first visible sign. Later on nodules, and finally ulcers, appear on the nasal mucous membrane, and swelling of the submaxillary glands follows. Frequently there is cough and dyspnœa, and generally some irregular fever; wasting is marked; and in the late stages there may be œdematous swellings of the limbs, abdomen, and chest.

Glanders of the skin is less common in chronic glanders than in acute, the favourite sites being the limbs, shoulders, breast, and hypogastrium. The nodules or boils ("farcy buds") vary from a pea to a walnut in size, and may disappear to some extent, although they generally undergo change into ulcers; the efferent lymph vessels are swollen into knotted cords, the heads of which often become ulcerated. Affected lymphatic glands are often enlarged, and later become indurated or suppurate.

In man the disease is set up by direct inoculation of the infected secretions, usually into an abrasion of the skin. The parts usually infected are the hands, the nasal mucous membrane, the lips, and conjunctivæ. Infected parts become swollen and painful, and the lymphatics inflamed; there is fever; nasal discharge; ulcers on the nasal mucous membrane; pustules and abscesses in the skin; ulcers in the mouth, pharynx, and larynx, and on the conjunctiva; articular swellings are often present; and sometimes intense gastro-enteritis. Death may ensue in from a fortnight to a month, or the disease may become chronic. The fatality is great unless the disease is strictly localized, and is treated early by cauterization.

A horse showing no outward symptoms of the disease may be glandered, and a source of infection to others. The diagnosis is assisted by the inoculation of other animals (field mice and guinea-pigs) for the observance of symptoms, and by the injection of "mallein." Recently, too, the Widal reaction has been used to diagnose the disease.

"Mallein" is a preparation made from the bacilli of glanders in a manner analogous to tuberculin. It is injected subcutaneously at the base of the neck, after the animal's temperature has

been taken. The increase in temperature within twelve hours should exceed 2° C. for a certain diagnosis, and 1·2° C. to warrant suspicion. There is also a large painful swelling at the site of inoculation (in the horse), and a swelling of the farcy buds.

The preventive measures which should be taken against the disease have generally been restricted to those embodied, in 1892, in an Order of the Board of Agriculture. That Order provided for compensation for slaughter of affected and suspected animals, and certain powers were given for securing the examination of horses by veterinary surgeons, and for controlling the disease when discovered. Dead bodies were ordered to be buried 6 feet deep in their skins, and covered with a sufficient quantity of quicklime or other disinfectant; or the local authority was empowered, with the consent of the Board, to have the body, which had been disinfected prior to removal, cremated or treated by chemical agents.

Complete measures of prevention and stamping out would include: (1) A systematic and repeated inspection of horses in affected localities, and the employment of "mallein" for diagnostic purposes; (2) the avoidance of common drinking troughs; (3) the prompt separation of all suspected horses and the slaughter of all diseased ones; (4) the prompt cleansing and disinfection of infected premises; and (5) newly purchased horses to be quarantined before being introduced into a stud.

A Departmental Committee, which reported on glanders in 1899, made the following recommendations:

1. That the Board of Agriculture should exercise a more extended supervision of the working of the Glanders or Farcy Order.

2. That notification should be made either to a constable or to a veterinary inspector.

3. That where practicable the local veterinary inspector should not engage in private practice.

4. That it should be made obligatory for veterinary surgeons to notify cases of glanders of which they become aware.

5. That occupiers or owners of knacker's yards should notify any case of glanders found in animals taken to their yards for slaughter.

6. That horses that react to the "mallein" test should be considered as possible sources of infection.

7. That horses that the veterinary inspector may consider to

have been exposed to contagion should be dealt with in the same manner as suspected horses, but with certain reservations.

8. That the slaughter of all animals showing clinical symptoms of glanders should be made compulsory.

9. That compensation for horses slaughtered solely on account of reaction to the "mallein" test should be on a higher scale than that for a "clinically" diseased horse.

Many of the foregoing recommendations have been adopted in the Glanders or Farcy Order of 1907.

Variola.

Variola occurs in most of the domestic animals. Cow-pox (variola in the cow) was first experimentally transmitted to man, in 1796, by Jenner, who proved, in 1798, that it conferred immunity from small-pox. The close relationship existing between the various kinds of variola found in man and other animals is proved by their reciprocal power of conferring immunity. Cow-pox in man is protective against small-pox, and the latter is also protective against the former.

The symptoms of variola in animals (which appear after an incubation period of about a week) are divided into several stages: (1) The prodromal stage, which lasts a day or two, is characterized by fever, catarrhal affection of the mucous membranes, and erythema of the skin; (2) in the eruptive stage, lasting from six to eight days, red spots suddenly appear, which become nodules of the size of a pin's head, surrounded by a red ring, and which after a few days form bluish-white vesicles, often with a depression in the centre; (3) in the stage of suppuration, which lasts two or three days, the vesicles become pustules, and the temperature, which had fallen during the eruptive stage, again rises; (4) in the stage of exsiccation, which lasts from three to five days, the pustules dry up into yellowish, and later on into dark brown, crusts or scales, which fall off, leaving shining red cicatrices.

Sometimes the eruption is confluent, and the type of the disease may also be hæmorrhagic.

Cow-pox chiefly attacks young cows, the eruption being generally confined to the teats and udder; fever is absent or slight; and the prognosis is very good. The disease spreads slowly in a shed from animal to animal, and the eruption lasts altogether about twenty-one days.

The lymph of cow-pox, or "vaccine," was introduced for vaccination in man by Jenner in 1798. As cow-pox is comparatively rare, "humanized" vaccine, or vaccination from man to man, was subsequently employed; but owing to the drawbacks attending this practice, animal vaccination has been recently reintroduced. For the cultivation of the vaccine, calves three to six months old are taken, the skin over the lower part of the abdomen is shaved and disinfected, and the lymph from a previously vaccinated calf is inoculated. Vesicles mature in from four to five days, and the lymph collected from these is used for human vaccination or for the further inoculation of calves. One calf yields from 1,000 to 3,000 doses of lymph. The vaccine may be preserved in (1) capillary tubes, in which it loses strength and becomes inert; or (2) it may be kept in the dry condition by scraping off the lymph and crusts, drying them, and then placing them between two glass slides and sealing with paraffin—the vaccine then keeps for months; or (3) it may be rubbed down with glycerine and preserved in capillary tubes.

Mange.—Man is infected with this parasitic disease by contact with mangy horses and their grooming tools, etc. Mange in the dog and cat is also transmissible to man.

Ringworm may be communicated to humans by the horse, calf, dog, cat, etc. In country districts the calves constitute the chief source of infection from the lower animals, and in towns the cats spread much of this disease.

Scarlet fever is said to affect the lower animals, but this is probably due to a confusion of the disease with petechial fever—a disease characterized by hæmorrhages in the skin and internal organs, such hæmorrhages in the skin varying in size from a pea to a half-crown piece.

Scarlet fever in man has probably no sort of relation with any disease of cows. Klein's statements as to the relationship between human scarlet fever and a bovine eruptive fever have never been confirmed, and cows have been proved to be immune to human scarlet fever (Crookshank, MacFadyean, Edington, McCall, Axe, and others).

Bubonic plague may affect rats, pigeons, mice, cats, monkeys, and pigs; and flies, fleas, and mosquitoes may communicate the disease.

The *cholera* of birds (fowl typhoid); *swine erysipelas, swine*

fever, or *hog cholera; epidemic pleuro-pneumonia* in horses, bovines, and goats; *cattle plague, splenic apoplexy*, and *quarter ill*, have not been shown to be communicable to man.

Whether the *dysentery* of cattle and domestic animals, the *influenza* of horses, asses, and mules, and the *diphtheria* of birds, calves, and pigs, are etiologically identical with the similarly termed diseases in man is at present unknown, but the balance of evidence is opposed to such a view. The disease called "*thrush*" in human beings is found in calves, foals, and birds, and is due to the same fungus.

The Piroplasmoses.

This term embraces a number of distinct infective diseases, the causative agent—a piroplasma—being transmitted from one animal to another through the agency of ticks. The piroplasmata are protozoa. They are pea-shaped micro-organisms, and are found singly, or in pairs, or in multiples of pairs within the red blood corpuscles of an infected animal. Larger sausage-shaped extracorpuscular parasites are also described by Nuttall, which he thinks may be gametes, as they resemble the malarial crescents of human blood. The diseases caused by piroplasmata are Texas fever (redwater of cattle), Rhodesian fever (cattle), and Carceag (European sheep). There is also piroplasmosis of the dog (South Africa), horse, donkey, and mule (South Africa), monkey (Uganda), and Rocky Mountain fever in man, which is also probably due to piroplasma infection. In Brazil fowls are apt to suffer from spirochæte disease, which is a tick-transmitted infection, the spirochæte greatly resembling the spirillum of relapsing fever in man.

All these diseases commence with fever, followed by a great destruction of blood corpuscles by the piroplasmata, and the serum becomes tinged with hæmoglobin, which finds its way into the urine. Hæmoglobinuria and icterus are the usual, but not invariable symptoms. Manson has pointed out the similarity between the piroplasmoses and blackwater fever of man, as regards the characteristic symptoms—hæmoglobinuria and icterus, the latter disease being usually regarded as a manifestation of malaria. Immunity from a fresh attack follows upon recovery in piroplasmosis, but the immunity appears to be due to the fact that the parasites persist for long periods in the blood of recovered animals, although not demonstrable microscopically.

Consequently, such animals may be the means of propagating infection indefinitely in tick-infected countries.

The ticks, which are the carriers of the piroplasmata from infected to healthy animals, belong to the class *Arachnoidea* (spiders, mites, etc.). They derive their nourishment entirely by sucking the blood of their hosts (terrestrial vertebrates). Ticks are very widely distributed, but they are most numerous in warm countries. The eggs are laid by the female tick in recesses in the ground, and after some time six-legged larvæ are hatched out and crawl upon the surrounding vegetation. Here they wait their opportunity, until they can attach themselves to a warm-blooded host, whose blood they suck. In some species of ticks, the larvæ having gorged on blood, drop off the host on to the ground, there to undergo their metamorphosis into eight-legged nymphæ, which in turn attach themselves to a fresh host, and again drop off when gorged, to develop on the ground into adult ticks. In other species the metamorphosis from larva to nymph may take place upon the host; and in other species again the whole cycle of changes from larva to adult tick may take place on the host. It follows, then, that in some species only the adult ticks act as carriers of the piroplasma parasite, whilst in others larvæ and nymphæ as well as adult forms may play their part in propagating piroplasmosis.

The Investigation of Disease Outbreaks.

In endeavouring to arrive at the cause of an outbreak of disease in a community, it is very seldom possible to obtain *absolute and positive* proof that a certain circumstance and certain phenomena stand in the relation of cause and effect. It is generally only *feasible* to show that there is a greater probability in favour of one set of circumstances being the cause of the outbreak than of any other set, because of their more direct relationship to the phenomena observed.

In tracing the origin of any outbreak, all the antecedent facts should be ascertained with regard to every individual instance of illness, with a view to subsequent comparison of the factors respectively of agreement and disagreement in relation thereto. In addition, similar inquiries sometimes should be made in respect of persons living under apparently identical conditions with those who have been attacked with illness, but who have not

themselves fallen victims, with the object of ascertaining if there is a strongly dividing line separating the antecedents of the sick from those of the healthy.

The method of reasoning employed is that which is known in logic as the *joint* (*inductive*) *method of agreement and difference.* If on inquiry it has been ascertained that a particular antecedent is traceable in the history of all cases that have developed illness, whilst this particular antecedent has been as invariably absent in the previous history of the persons otherwise similarly circumstanced, but who have remained unaffected, such antecedent is the probable cause of the illness—the probability increasing as the number of incidents which conform with the facts increase.

Thus, for example, if in an outbreak of acute gastritis from supposed ptomaine poisoning, affecting a number of people who partook of a common meal, it is ascertained that those affected all partook of a particular dish, whilst those unaffected as invariably abstained, the presumption would be very strong that the implicated dish contained the poison which was the cause of the illness; and the greater the number of those from whom this evidence is obtained, the more likely is this presumption to be true. In outbreaks of infectious illness, however, the essential facts are always more difficult to obtain, and when obtainable are not always recognized as having any direct relation to the observed phenomena, partly because the incubation period of such diseases is much longer than in cases of acute irritant poisoning, and the incubation period itself is subject to greater variation, and partly because there is more than one possible cause—often a multiplicity—which have to be borne in mind by the investigator. This is especially true of epidemics of enteric fever, where the incubation period may vary from seven to twenty-one or more days, and the infective agent may be introduced into the body by a variety of channels. To separate out in a possible period of over a fortnight those antecedents in the previous history of an enteric fever patient which are of direct concern, from irrelevant details which can have no bearing upon the point at issue, is a work which can only be adequately performed by a mind trained to elucidate such phenomena, and well stored with the knowledge which alone can serve to separate efficiently the wheat from the chaff.

In such investigations conclusions are often arrived at which carry little conviction to the minds of critical observers; and

this frequently happens from the adoption alone of the inductive method of agreement, the method of difference being too often discarded. It cannot be too much insisted upon that the collection of certain data showing that all the cases of illness have had a common antecedent—such, for instance, as the consumption of a certain water or food within the supposed period of incubation —is no proof that such antecedent is the cause, in the absence of further proof that, in respect of others living under similar conditions, but who are unaffected, their previous history is unassociated with the particular antecedent circumstance which is so invariably present in the history of those affected.

In many instances it must happen that the antecedent suspected of being the cause is only found in a majority of the instances where illness has ensued—not in all, and is even present in some few instances where illness has not ensued. These exceptions are often capable of explanation, and do not necessarily invalidate the whole argument, where the origin of infectious disease is concerned.

A good rule for the investigator to bear in mind is to be very careful to exclude all the more commonly recognized causes, before he ventures to assign as a cause some circumstance of an unusual character in that connection, which appears to him to fit in with the facts. Sometimes the facts appear capable of explanation on two hypotheses, one more or less familiar and easily intelligible, the other more novel and puzzling. The first should be excluded, as far as exclusion is possible, before the second is adopted.

Sometimes the experimental method is available as an aid to the arrival at a sound conclusion of the cause of an outbreak or epidemic; and it occasionally happens that what are to all intents and purposes unconscious "experiments" occur to verify hypotheses previously unsubstantiated. For instance, an outbreak of diphtheria in a school is attributed to the presence of a boy with a chronic nasal ulceration and discharge. The boy is sent to his home, and the outbreak terminates. On his return to school some weeks later, other boys, who have relation of some sort with him, develop diphtheria, and bacterioscopic examination shows that the Klebs-Loeffler bacillus is present in the nasal secretion of this boy, who has been the unwitting carrier of infection. Again, experiment on a large scale has demonstrated that rats carry the infection of plague, and are a means of con-

veying it to man; and the part played by mosquitoes (Anopheles) in the propagation of malaria has been strikingly confirmed by experiment on the human subject; and the same is true of yellow fever.

In conclusion, it may be said that in any investigation of a disease outbreak, the really important matter is the due appreciation and collection of all the facts which have a bearing on the subject, and their marshalling in a systematic and intelligent manner. It may be possible on these foundations to hypothesize a cause for the outbreak; but should this be unascertainable on the facts reported, there is no reason to deplore a failure which in the light of future knowledge may be capable of explanation. It is far better to record the facts irrespective of any theory as to their origin, than to endeavour to make the facts fit the theory.

Modern Views on Isolation and Disinfection.

Laboratory experiments in the cultivation and propagation of specific pathogenic bacteria, and the greater precision of epidemiological findings and data, tend to emphasize the importance of close proximity and personal contact in the transmission of the infections of most of the specific diseases from the sick to the healthy. By personal contact is not necessarily implied actual touching of sick and healthy, but rather such proximity of persons that specific germs can pass easily from the one to the other. In coughing, sneezing, and loud talking the bacteria ejected from the lungs, throat, nose, and mouth may be taken into the air passages of those in close proximity. The shaking of hands, the act of kissing, and the handling of clothes or other articles recently worn or touched by an infectious person, may all be the means of enabling specific germs to spread from the sick to the healthy. The hands once infected may very easily convey the infection to the mouth, and are probably as frequent a source of the transmission of disease as all other methods combined.

It was formerly thought that infection remained for possibly long periods in the clothes, the furniture, and the dust on the walls and floors of the infectious sick-room. There is reason, however, to believe that the pathogenic microbes of most of these diseases do not long retain their vitality or their virulence outside the human body. The exceptions are anthrax and

tetanus, owing to the formation of highly resisting spores by these specific organisms when separated from the living tissues. The consensus of scientific opinion is now to the effect that infection passes as a rule directly from the sick to the healthy, except in the two diseases above mentioned, and in enteric fever, paratyphoid fever, cholera, and dysentery, where the specific organism is for the most part contained in the excreta, and so becomes the means of contaminating water, milk, shell-fish, etc.; but contact infection in these diseases is by no means uncommon.

The older belief in fomites and infected articles as transmitting disease was held in the days when nothing was known of carriers, and when little account was taken of mild and undiagnosed cases as transmitters of infection. Outbreaks which could not be traced to any definite source were attributed to infection retained in inanimate objects. It is now, however, recognized that it is far more likely that infection arises from a carrier, or a missed case of the disease, than from any ability of specific organisms to retain their virulence beyond a certain very limited period after discharge from the body. Carriers are probably potent sources of infection in diphtheria, cerebro-spinal fever, acute poliomyelitis, encephalitis lethargica, influenza, enteric fever, cholera, and dysentery—in all these diseases there being a recognized specific causative microbe. In such other diseases as small-pox, chicken-pox, scarlet fever, measles, German measles, and mumps, carriers are not known, as the specific germ is unrecognized; but the missed case—the mild unrecognized form of the disease—plays undoubtedly a considerable part in propagating infection, and it is quite probable that one or more of these diseases are liable to be carried by persons who present no symptoms of infection, but are capable of proving infective to others.

It follows that if measures of isolation are to be in the highest degree effective, it is not only necessary to isolate the actually infectious sick, whose illness is recognized, but also the mild cases which receive no medical attention, and the carriers, who present no symptoms of illness. It will be at once seen that there is no possibility of isolation on any such scale as this, and that even the best methods of isolation in home or in fever hospitals must necessarily fail to take account of a large amount of possibly infective material in the general population. It is this unrecognized infective material that is chiefly responsible for the con-

tinued maintenance of scarlet fever and diphtheria amongst our urban populations, notwithstanding very complete systems of hospital isolation for the infectious sick.

The practice of routine disinfection of sick-rooms and bedding and clothing after recovery from scarlet fever, diphtheria, and other compulsorily notifiable diseases, is still carried on very much as before. Its necessity may now very well be doubted in the light of our more exact knowledge of the life-history of infective organisms. Still the public expects it, and would not readily acquiesce in its abandonment. Moreover, there is at least a possibility of the survival of infection in inanimate objects under certain special circumstances; and until our knowledge of the processes of infection is more exact than it is, it will be wise not to prematurely abandon a ritual which may be unnecessary, but is at any rate sanctioned by custom and expected by the public. It is, besides, a useful object lesson of the need for special precautions.

The Isolation of the Infectious Sick.

This can only be attained by a system of *compulsory notification* of all infectious diseases to the Sanitary Authority of the district. It will then generally be possible to isolate the first case or cases of the disease as they occur, to destroy the infection already generated, and to control the movements of the individuals with whom the sick person may have come into contact. Without compulsory notification it must almost necessarily happen that the disease obtains headway before it is recognized, and then the most persevering efforts too often fail to obtain such a control as will prevent its widespread dissemination.

There are many who are in favour of a greater extension of the range of notifiable diseases, and would advocate the notification of influenza, syphilis and gonorrhœa, septicæmia, purpura, and acute rheumatism. As preventive measures are not limited to the control of infective diseases, good results might follow, and much valuable knowledge would accrue by the adoption of some system of compulsory notification of certain non-infectious illnesses.

The *isolation* of all cases of contagious disease must be regarded as a most desirable measure, but is more usually carried out in the case of the epidemic diseases with possibly air-borne contagia,

such as small-pox, scarlet fever, and diphtheria. Enteric fever cases are usually isolated owing to the danger of contact infection in the home, and the risk to water and food if the excretions are not properly disposed of. Tubercular diseases are rarely isolated, but it is probable that such a measure applied to "open tuberculosis" with discharges, especially the later stages of pulmonary tuberculosis, would have a considerable effect in limiting their spread. The more usually inoculable diseases—with the exceptions of leprosy, where segregation of the sick should be rigidly enforced, and of contagious ophthalmia—do not seem to demand measures of isolation.

A difficulty arises in the case of measles that the pre-eruptive stage is infectious, and that before the isolation can be effected other susceptible persons have probably caught the infection. In measles and whooping-cough, also, the contagion is so diffusible and universal that few can hope to escape; and the tender age of the sufferers in these and other infantile complaints renders them less suitable for hospital treatment than is the case with older children and adults.

Where removal to hospital is not feasible, isolation must be attempted by placing the patient in a room by himself at the top of the house, all communication with the other inmates being forbidden; and the aerial connection between the sick-room and the rest of the house must be broken as much as possible by hanging up outside the door a sheet kept constantly soaked with some disinfectant liquid. Nothing must be allowed to pass out of the sick-room unless previously disinfected, and all dressings, poultices, and rags should be immediately burnt after use.

Hospitals.

The aggregation of a large number of sick persons suffering from a variety of diseases or recovering from surgical operations in one common building is a necessity of modern life, but is now recognized as being often attended with risks and dangers from which the patient treated in his own house is to a large extent exempt. In former times this crowding together of the sick in hospitals led to outbreaks of erysipelas, pyæmia, and hospital gangrene in the surgical wards, the contagion appearing to be conveyed from one patient to another through the air, or by means of the hands or instruments of the surgeon or nurse. The

aseptic treatment of wounds and injuries, and the greater care bestowed on the construction and management of hospitals, have eradicated these terrible diseases from modern hospital practice; but when from any cause the surgical wards of hospitals are overcrowded, and the cleanliness and frequent dressings of wounds cannot be attended to, these septic diseases are almost sure to make their appearance.

It has often been noticed that cases of open wounds from injury or operation recover far more rapidly when treated in the open air, or in huts and tents practically open to the air, than when confined in close buildings; and the same is true of most acute infectious diseases.

The first principle, then, in hospital construction and management is bound up in an abundant supply of pure air to the patients. The putrescent organic effluvia from the skins and lungs of sick persons must be diluted with fresh air and rapidly carried away. For each patient in a medical ward the superficial floor space should not be less than 100 square feet, and the cubic space 1,000 cubic feet. The air should be changed at least three times in an hour, which would give 3,000 cubic feet of fresh air per head per hour.

For *infectious disease* hospitals the minimum floor space should be 144 square feet, and the minimum cubic space 2,000 cubic feet per head, changed three or four times an hour. Each bed should have at least 12 linear feet of wall space. The window surface should be in the proportion of 1 square foot to about every 70 feet of cubic space, in order that the wards shall be well lighted. At night time the wards are best lighted by electric light, and failing that by incandescent gas burners.

Hospitals constructed on the open-air system, where one side of every ward can be opened out by throwing back all windows, which are contiguous, so that one side of the ward is open to the air, need only provide 60 to 68 superficial feet of floor area per bed, and 600 to 800 cubic feet per bed. This is the system of construction now adopted for war hospitals.

For *general* hospitals it is found that the most convenient number of patients that may be treated in one ward is on an average thirty, this being the number which one nurse can readily supervise. In an *oblong ward* with thirty patients, each patient to have 100 square feet of floor space and 1,000 cubic feet of air space, 3,000 square feet of floor space will be required

and 30,000 cubic feet of air space. The 3,000 square feet of floor space will be available if the ward is 120 feet long and 25 feet wide. As there are fifteen beds on each side of the ward, the longitudinal wall space for each bed will be 8 feet, and the distance between any two beds (themselves 3 feet wide and 6½ feet long) will be 5 feet. The width of 25 feet is a convenient one, as it allows a passage 11 feet wide between the two rows of beds for the whole length of the ward, and permits of thorough cross-ventilation between the opposite windows, and the flooding of every part of the ward with daylight.

To provide the 30,000 cubic feet of air space the ward must be 10 feet high. It would be better to have the height of the ward 12 feet, which would allow 1,200 cubic feet of air space per patient. Any height above 13 or 14 feet is useless for purposes of ventilation, and should be discounted in calculating the cubic space per head.

There is a growing disposition to provide small wards in fever hospitals, as such wards appear to be more favourable to the patient's recovery and to reduce the risk of secondary infections. They facilitate, moreover, some classification of the patients according to the severity of the attack and the stage in the disease at which they have arrived. It is desirable to provide a little extra space in the female wards, as children of both sexes may be nursed in them.

"Cubicle isolation" of fever cases was first introduced by Dr. Biernacki in 1906. By cubicle or bed isolation, or the "barrier system," is implied either the separation of beds in a common ward by partitions (of glass to a height of 7 feet), or the system in vogue at the Institut Pasteur, and elsewhere, where the ward is divided into a number of self-contained chambers each separately ventilated. While the patients may talk together, they may not communicate in any other way. The method has been tested at several hospitals. A lavatory basin over which is fixed a tepid spray worked by pedal action is placed in each cubicle, which also contains a separate overall for nurse and medical officer, and a distinct set of articles (including thermometer) and appliances for each patient. Patients suffering from scarlet fever, rubella, diphtheria, measles, whooping-cough, chicken-pox, typhoid fever, cerebro-spinal fever, and mumps have been so isolated; and as the result of the observations hitherto made, it appears that non-septic scarlet

fever, diphtheria, measles in the post-eruptive stage, rubella, whooping-cough, typhoid fever, and mumps, can be so treated without fear of accident. The use of such cubicles possesses advantages over separate isolation wards in point of economy in construction and in staff, greater convenience in nursing, and an educational value in the training of nurses. Everything depends on the rigid fulfilment of the prescribed routine by nurses and medical officers, when attending to the patients in their charge, and free ventilation is of the greatest importance.

Provision should be made for the entrance of warmed fresh air to the wards in winter; this may be effected by Galton's ventilating open fireplace, or by a ventilating stove or stoves placed in the centre of the ward. Shorland's Manchester grates are much used. For warming purposes, hot-water pipes should also be placed in the ward, as they may be required during very cold weather. They should be placed in a position convenient of access for cleansing any space behind or below them, and should not be fixed in channels or chased recesses in walls or floors. Radiators heated by hot water are now more commonly used than "hot-water pipes."

To secure the best kinds of natural ventilation, the ward should have opposite windows reaching nearly to the ceiling, and the upper portion of each window should be provided with side flaps and made to revolve on its lower border into the ward, so as to admit fresh air during warm weather in an upward, slanting direction. Hinckes-Bird's arrangement may also be applied to the windows. It is sometimes desirable to have an inlet for fresh air, which can be warmed in winter, close to the floor at the head of each bed, in order to ventilate the space under the bed, and at once carry away the respired air and effluvia from each patient. The inlet is now generally arranged in connection with the hot-water radiator. For the escape of the heated and vitiated air, extraction shafts may be provided, opening near the ceiling, which should be joined together, the single shaft so formed being then carried up in close contact with the stove or chimney flue, in order that the column of air in it may not be allowed to cool and hinder the up draught. In summer, when the stoves are not in action, the same result may be produced by burning gas in Bunsen burners at the bottom of the extraction shafts, or by means of a revolving fan at the top of the shaft.

Recent experience, however, shows that extraction shafts,

unless easily accessible throughout their entire length for cleansing, are undesirable, and it is preferable to rely upon window openings and chimney flues for the escape of vitiated air.

In the ventilation of hospital wards, the "propulsion" or "plenum" method is regarded with favour, because when air is propelled into a building the source of supply can be chosen, and the air can be cleansed, warmed, and brought to a suitable hygrometric condition. The chance of infection being carried aerially from ward to ward is lessened, from the circumstance that the air supply to each ward can be kept quite distinct and separate. There is, however, one condition essential to the success of the "plenum" system of ventilation, which is generally regarded with disfavour, viz., that the movement of air must be kept absolutely under control, and consequently that the opening of windows cannot be permitted; moreover, the maintenance of the air at the same uniform temperature, humidity, and rate of movement, tends to have an enervating and depressing effect upon patients and nurses. For this reason the system is not now regarded with favour for hospital purposes. The General Hospital at Birmingham is ventilated on the plenum system. In this building the main air ducts are carried under the corridors, from which separate flues are carried up to the several wards, the air outlets being at the floor level. The vitiated air is carried away through ventilating turrets at the ends of the wards. Where an extraction system alone is relied upon, the entering air is incapable of regulation, both as to its source and its amount.

The water-closets, bath-rooms, and slop-sinks should be placed in a block outside the ward, but connected with it by a cross-ventilated lobby. By this means, if disconnection of waste pipes and ventilation of soil pipes are properly attended to, there is no risk of foul drain air gaining access to the ward. Proper hospital slop-sinks are necessary for washing and emptying bed-pans, spittoons, and urine slippers. They should be made of porcelain, enamelled fireclay, or aluminium, should be of large size, at least 15 inches square at the top, with upward sluice or jet for cleansing the bed-pans, and should be flushed from a water-waste preventer. The flush to cleanse the sink and the jet of water for the irrigation of bed-pans, etc., may be controlled by means of treadles actuated by the foot, the knee, or the elbow, so that the hands may be left free for holding the utensils.

Almost as important as good ventilation is the provision of internal surfaces (walls, floors, and ceilings) to the wards, which will not hold or absorb organic effluvia. The occurrence of erysipelas and surgical fever in the past has been favoured by wooden floors with chinks and crevices between the boards. The organic matters from poultices and dressings find their way into these crevices, and accumulate under the flooring.

The floors of the wards should be covered with oak parqueterie, or with solid wood-block flooring without chinks or cracks, laid on a bed of concrete. Narrow, well-seasoned deal boards, tongued and grooved, are less satisfactory, but far cheaper. The surface should be painted, or stained and varnished, and kept clean without washing. The parqueted floors should be oiled and beeswaxed; or melted paraffin may be ironed into the woodwork, which it penetrates for about $\frac{1}{4}$ inch, forming an unbroken surface which remains good for years.

Other materials for hospital floors are teak and maple boards (tongued and grooved), linoleum laid direct on the coke-breeze cement of the fireproof floor, terrazo (marble chips set in cement), and various patented materials like "doloment," "stonwood," and "eubæolith," which are formed of compressed sawdust, shavings, and cement. Terrazo is rather cold and slippery, and the patented floors are liable to crack. Linoleum is found to answer well, as it is warm, elastic, and non-slippery. It should not be laid over a boarded floor.

It is most essential to avoid washing floors with water. The air of the wards is by this means chilled from evaporation when the floor is drying. All cornices, corners, and ledges should be avoided in the wards, and angles rounded off, so as to offer every facility for cleansing.

The wall surfaces should be impermeable. Glazed brickwork or glazed tiles set in Portland cement afford, perhaps, the best and most easily cleaned surface, but they are apt to condense moisture on their surfaces. The walls may also be coated with Keen's cement or Robinson's fireproof cement, painted, or even distempered, if tiles are too costly. Ceilings may be cemented and painted, or limewashed.

The bedsteads should be of iron, with spring wire mattresses, and, in the surgical wards, provided with movable fracture boards. It is very important to reduce the furniture of the ward to a minimum, and to allow no curtains, hangings, or drapery of any sort.

Excreta, sputa, dirty dressings, and poultices must be removed from the wards at very frequent intervals. In the case of infectious disease hospitals, it is very desirable that the solid refuse matters should be burned. This can be done by means of a small destructor furnace in connection with the boiler-house or heating furnace of a large hospital.

No harm has been shown to result from allowing the drains from a fever hospital to empty into the public sewer, or from the slop waters being disposed of by sub-irrigation.

For the exercise of the patients, covered balconies on the southern or western aspect of the building should be provided, and in large towns, where space for a garden is wanting, a flat roof affords a valuable exercise and recreation ground.

In some of the more recently constructed hospitals, it has been found convenient to place the kitchens and sculleries at the top of the building, and to use gas and steam for all culinary purposes.

Every town should have hospital accommodation for the isolation of cases of infectious disease. The amount of accommodation required will depend upon the character of the population and the rate of its increase, the housing and the habits of the people, and the amount of intercourse with other places from which infectious disease may be introduced; but it may be stated generally that there should be at least one bed to every 1,000 of the population, when this is largely composed of the industrial classes. A site should be chosen outside the town, in a thinly populated neighbourhood, with a southern exposure, a dry subsoil, a good fall for drainage, and easy of access from the town. Separate pavilions should be set aside for the separate accommodation of each different disease to be treated. The best arrangement is to place the pavilions on a north and south line, with easterly and westerly aspects, so that every side can receive sunshine.

Where space will admit, the system of one-storeyed pavilions is far the best for all hospitals, and is especially suited for those intended for infectious diseases. The pavilions are connected with one another and with the administrative blocks by corridors which are, or may be, open to the air; and all risk of transference of foul air and effluvia from one ward to another is thus avoided. In large towns a certain amount of crowding on a limited area is unavoidable, and wards of two or more storeys in height must be built. Even in these the system of disconnected pavilions

should be aimed at, and the staircases require careful planning to prevent them acting as shafts for the passage of air from one ward to another. The external air space around the wards should be ample, and overshadowing by high buildings in the neighbourhood must be carefully avoided.

Hospitals constructed of *semi-permanent* material have been found successful in the British Army, and the same principle is now being applied in civil hospitals. The weight of the structure is taken by steel uprights and girders resting on concrete foundations, whilst the wall spaces between the steel supports are filled with hollow bricks of earthenware or terra-cotta. The air cavity acts as a non-conductor, and prevents loss of heat. Such buildings are much cheaper to erect than permanent brick structures, and are likely to prove much more lasting than galvanized iron and wooden buildings. The wards should be warmed by hot-water radiators, as well as by open fireplaces, especially where the building is in an exposed position. Similar buildings have been constructed of steel framework with double uralite slabs, so as to form a hollow wall. If such buildings are erected of more than one storey, the floor should be of fireproof construction (coke-breeze cement resting on steel girders).

In epidemic periods it may be necessary to supplement existing hospital accommodation, and for this purpose tents (in summer) or huts of galvanized iron, wood, Willesden waterproof material, or Dœcker's material (a waterproof composition resembling leather), can be erected. Huts of the last three materials are preferable to iron, as they are easier to warm. The floors should be raised a foot from the ground, and the ridge of the roof should be used for ventilation as well as the windows. If these huts are constructed with hollow walls, the temperature in cold weather can be properly maintained with efficient ventilation—a difficult task without hollow walls, owing to the thinness of the materials. As the wood and waterproof compositions used in the construction of these hut hospitals are liable to rot and decay, they can only be regarded as temporary structures, and as soon as the emergency which necessitated their erection is over, they are best pulled down and destroyed.

As the late Sir Richard Thorne pointed out, the provision for isolating infectious cases is best carried out with deliberation in non-epidemic periods. Extemporized hospitals, erected to meet the demands of a sudden outbreak, are often not ready for occupa-

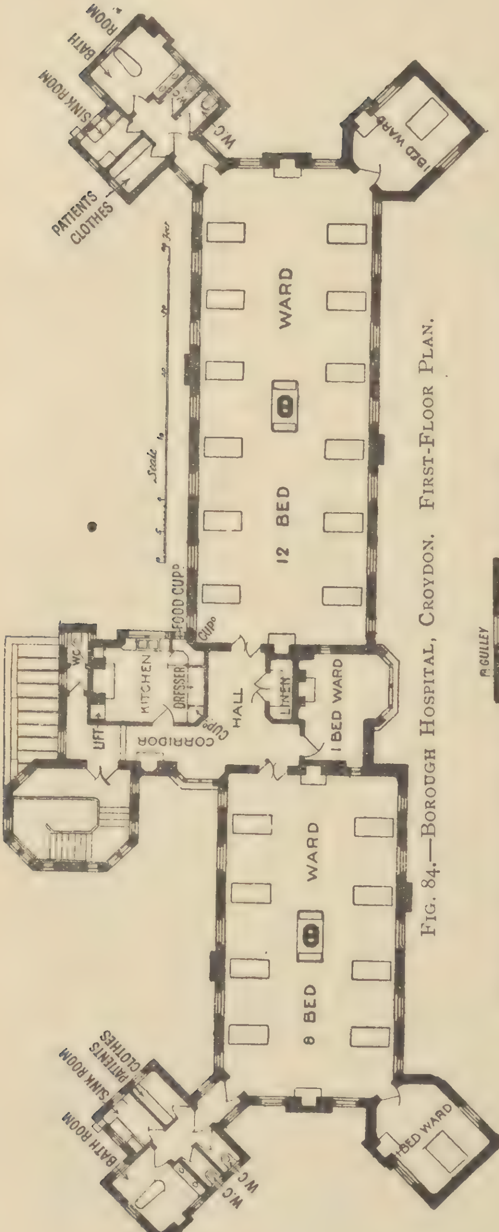


FIG. 84.—BOROUGH HOSPITAL, CROYDON. FIRST-FLOOR PLAN.

FIG. 85.—ISOLATION HOSPITAL BLOCK (AS RECOMMENDED BY THE LOCAL GOVERNMENT BOARD).

tion until the immediate cause for their erection has passed by, and they provide accommodation of a very indifferent sort. A memorandum of the Local Government Board states that in a village a small cottage, capable of isolating four cases in two separate rooms, should at least be provided; but a minimum in other cases should be four small permanent wards of brick, stone, or concrete, this accommodation being capable of being extended, if need be, by tents or huts. As some future extension is almost inevitable, the administrative block should be built in excess of the requirements at the time of construction. It is never desirable to accommodate more than twenty persons per acre, and the hospital buildings should always be 40 feet from the boundary fence, which should be at least 6 feet 6 inches in height. Temporary (wood and iron) hospitals are not approved of by the Local Government Board; for if these are constructed so as to ensure a fairly equable ward temperature, the cost is about the same as that incurred in the erection of ordinary brick buildings, while they are less durable and more expensive to keep in repair. Moreover, wooden lined wards are not adapted to the varying needs of a permanent building, and the risks from fire are very great in such wooden structures.

Certain general regulations must be observed in all fever hospitals. No member of the staff must leave the premises without first changing the outer garments; tradesmen must never be permitted to pass beyond the boundary wall or fence; the visits to the patients should be limited to the nearest relatives and the most intimate friends of those patients who are dangerously ill, and then one visit only of fifteen minutes' duration should be sanctioned each day; all visitors should be made to wear overalls on entering the ward, and to wash their hands and faces on leaving it; they should also be warned against entering any public conveyance immediately after quitting the ward.

Hospital buildings will include ward blocks, an administrative block for the housing of the staff and stores, and out-offices, such as laundry, mortuary, and disinfecting station. The administrative block should be placed so as to control the entrance to the hospital grounds in the absence of a porter's lodge, and it should be built on a scale somewhat in excess of what may be first required, so that it will be sufficient for future extensions of the hospital.

CHAPTER X

MATERNITY AND CHILD WELFARE

For many years in this country a high rate of infantile mortality continued to prevail, although there had been a marked reduction in the general death-rate. It was evident to those concerned with the public health of the country that this loss of infant life annually recurring was largely the result of ignorance on the part of the mothers, and their adherence to outworn prejudices of long standing connected with the upbringing of infants. As a result, a movement was initiated early this century in the more enlightened districts to provide trained and experienced women visitors to give advice and encouragement to working-class mothers as to the proper methods of rearing their children.

It was soon seen that this system of infant health visiting was proving a success, wherever it was undertaken on sound principles. The infantile mortality rates promptly responded to the local efforts made; and it soon became evident that the movement, which was largely a voluntary effort by philanthropic agencies and persons in its initiation, would prove a very important means of improving the public health, if undertaken by Sanitary Authorities. Excessive infant mortality, as Dr. Newsholme has shown, implies excessive child mortality and unduly high death-rates right up to adult life.

Most of the more important County Councils and Sanitary Authorities throughout the country have now undertaken work of this character by the appointment of women health visitors to visit the homes of newly-born infants, the required information being obtained under the Notification of Births Acts, 1907 and 1915; some authorities have themselves inaugurated Infant Consultation Centres and Clinics, whilst others avail themselves of, and support financially, the local centres of voluntary agencies.

The movement has throughout been highly appreciated by the central government authority, the Local Government Board, and in its more educational aspects by the Board of Education,

and Government grants have now for some time past been available in aid of both municipal and voluntary efforts in this direction.

In the early days of the movement the scope of the work was largely limited to infants, and the period from birth to the attainment of one year of age. It was, however, quickly recognized that the child, between infancy and school age, could not be excluded from any system of control and supervision, if the best results were to be obtained. It is consequently now the aim of all complete schemes for the workers to keep in touch with the children aged one year to five years, and to endeavour to conserve their health during the early years of growth and development, when so many chronic and disabling diseases are apt to originate, if there is a failure to observe the early signs of perverted health.

The movement in favour of conserving infant and child life is now viewed on even broader grounds; and the desirability of watching over the health of the expectant mother, of bringing to full term and safe delivery the large numbers of abortions and still-births that are known to occur, and of providing skilled attendance in confinements for the mothers, so that they may the more completely undertake the duties and functions of motherhood, are seen to be all parts of a co-ordinated and complete scheme for preserving the national life and vigour.

The devastating effects of the war, the loss of so many men in the prime of life, and the permanent crippling of so many others, have brought home to the public, in a way never before experienced, the value to the nation of its young life. The continually falling birth-rate of the country is a peril to its future "man-power," on which so much depends. No one can tell whether it will be possible to arrest the fall of the birth-rate and again increase the productivity of the nation, but measures taken to save infant life, whether ante-natal or post-natal, are bound to be effective in a measure, for the experience of the past ten years has clearly so demonstrated.

Thus the solution of the problem of infant mortality is to be found in the circumstances surrounding the life of the mothers of the poorer classes, and especially the poorest class, who are fighting year in and year out against destitution and want. There is much machinery which has already been devised to bring about a reduction in infant mortality. It aims at more efficient domestic and municipal sanitation and housing, and

intelligent and painstaking motherhood. Paid official and voluntary women health visitors, schools for mothers, consultation centres for mothers, infant milk depots, the provision of cheap meals to expectant and nursing mothers, free gifts of nourishment to necessitous mothers with infants, clinics for mothers and infants, and some hospital accommodation for expectant mothers shortly before and during pregnancy, and also for infants, are all included in the provisions requisite for a complete scheme of maternity and child welfare.

There can be little doubt that artificial feeding and poverty are the chief factors in the problem, poverty connoting bad housing accommodation, poor and often ignorant feeding and clothing, and insanitation. The employment of mothers in industrial occupations shortly before and after the birth of the child has probably less influence on infant mortality than has been supposed.

An essential provision is a well-qualified official woman health visitor, who is assisted and directed in her work by a qualified medical man who has devoted some special study to infant hygiene and "mothercraft." Mothercraft implies carefulness; cleanliness of self, infant, and surroundings, including the preparation and storage of food; frugality; thrift; sobriety; early hours; and, above all, breast feeding. With the information obtained by the Sanitary Authority under the Notification of Births Act, the health visitor (assisted, if necessary, by a few voluntary workers of experience) can get into touch with the poorer mothers who have recently borne children immediately after the medical practitioner ceases his attendance, and by practical advice and stimulation much may be done to ensure that the child is tided over the dangerous first twelve months of life. While much may be done by home visitation, it is obvious that great advantages may be derived from the provision of an Infant Care or Child Welfare Centre to which parents may bring their infants on certain afternoons. Not only can the infant weighing and recording of the results (which furnish the best clue to the infant's physical progress, and greatly interest and stimulate the mothers) be better and more expeditiously performed, but the arrangement results in a great saving of the time of the health visitor. Furthermore, the establishment of a Centre admits of the temporary assistance of a medical man to co-operate with the health visitor, and furnishes valuable

opportunities for giving instruction to the mothers; it also serves as a distributing centre of food and clothing.

It is, of course, desirable to secure the sympathy of the medical profession and midwives if the Centres are to be really successful.

Medical education does not at present devote sufficient attention to infant welfare, personal and domestic hygiene, and other spheres of preventive medicine.

Maternity and Child Welfare Schemes.

In July, 1914, the Local Government Board forwarded to Sanitary Authorities a Memorandum on Maternity and Child Welfare.

In this Memorandum it is stated that a complete scheme for Maternity and Child Welfare undertaken by a Sanitary Authority should comprise the following elements:—

1. Arrangements for the local supervision of midwives.

2. *Ante-natal.*—(1) An ante-natal clinic for expectant mothers. (2) The home visiting of expectant mothers. (3) A maternity hospital or beds at a hospital, in which complicated cases of pregnancy can receive treatment.

3. *Natal.*—(1) Such assistance as may be needed to ensure the mother having skilled and prompt attendance during confinement at home. (2) The confinement of sick women, including women having contracted pelvis, or suffering from any other condition involving danger to the mother or infant, at a hospital.

4. *Post-natal.*—(1) The treatment in a hospital of complications arising after parturition, whether in the mother or in the infant. (2) The provision of systematic advice and treatment for infants at a baby clinic or infant dispensary. (3) The continuance of these clinics and dispensaries, so as to be available for children up to the age when they are entered on a school register—*i.e.*, the register of a public elementary school, nursery school, crêche, day nursery, school for mothers, or other school. (4) The systematic home visitation of infants and of children not on a school register as above defined.

The circular letter of the Local Government Board accompanying the above Memorandum impresses upon Sanitary Authorities the urgent need of preparing schemes to secure the health of

mothers and children, and to diminish ante-natal and post-natal infant mortality.

In 1915, the Notification of Births (Extension) Act was passed, which renders universal throughout the country the system of the Notification of Births Act, 1907. This Act also provides that the powers of a local authority may be exercised as regards maternity and child welfare in such manner as the authority direct by a committee, which shall include women, and may comprise persons who are not members of the authority. In any such committee it will be desirable to include working women, who might be representative of women's organizations. The Board considers that a majority of the committee should be direct representatives of the authority.

The Regulations under which grants will be paid by the Local Government Board in aid of maternity and child welfare work are as follows:—

1. The Board will pay grants during each financial year, commencing on 1st of April, in respect of the following services: (1) The salaries and expenses of inspectors of midwives. (2) The salaries and expenses of health visitors and nurses engaged in maternity and child welfare work. (3) The provision of a midwife for necessitous women in confinement and for areas which are insufficiently supplied with this service. (4) The provision of a doctor for the aid in confinement of necessitous women. (5) The expenses of a Centre—*i.e.*, an institution providing any of the following activities—viz., medical supervision and advice for expectant and nursing mothers, and for infants and little children, and medical treatment at the Centre for cases needing it. (6) Hospital treatment provided or contracted for by a local authority for complicated cases of confinement or complications arising after parturition, either in the mother or infant, and for infants found to need in-patient treatment.

2. The Board will not pay grants under these Regulations in respect of expenditure on schools for mothers which are eligible for aid under the Regulations of the Board of Education.

3. The grant paid in each financial year will be assessed on the basis of the expenditure incurred on the services referred to in Article 1 in the preceding financial year, and will be at the rate of one-half of that expenditure, where the services have been provided with the Board's approval and are carried on to their

satisfaction. The Board may, at their discretion, reduce or withhold the grant.

4. Grants will be paid to voluntary agencies aided by the Board on condition:—(1) That the work of the agency is approved by the Board and co-ordinated as far as practicable with the public health work of the local authority and the school medical service of the local education authority. (2) That the premises and work of the institution are subject to inspection by any of the Board's officers or inspectors. (3) That the records of the work done by the agency are kept to the satisfaction of the Board.

5. An application for a grant must be made on a form supplied by the Board.

6. The Board may exclude any items of expenditure which in their opinion should be deducted for the purpose of assessing the grant; and if any question arises as to the interpretation of these Regulations, the decision of the Board shall be final (September, 1916).

In a circular letter from the Local Government Board to County Councils and Sanitary Authorities (September, 1916), it is stated that comprehensive schemes should be undertaken by the Councils of County Boroughs, by County Councils, and by Metropolitan Borough Councils. As a general rule the smaller sanitary districts can be served more economically and efficiently by a county scheme than by separate schemes for each sanitary district, provided that proper co-operation with the Sanitary Authority is secured. The County Council may often combine in one individual officer the duties of health visitor, inspector of midwives, tuberculosis visitor, and sometimes also those of school nurse and mental deficiency visitor, and thus economize the time and travelling expenses of these visitors, secure uniform medical supervision and direction of their work, prevent duplication of inspection, and obtain a better class of officer.

Health Visitors.—The Board regard the provision of adequate home visiting as the most important element in any scheme of maternity and child welfare. Local authorities should, as a rule, aim at securing a staff equal to one whole-time health visitor for each 400 births. It is important that the visiting of children should be extended to school age, and that ante-natal visiting should be undertaken. The work assigned

to health visitors may properly include the visiting of cases of measles, whooping-cough, and diarrhœa in young children. The Board's grant is available in respect of this work, and in respect of the provision of nurses for young children suffering from measles and in need of this assistance. Now that all cases of measles are notifiable, it is desirable that visits should be paid to all notified cases, and inquiries made as directed by the Medical Officer of Health. During epidemics it may be necessary for the health visitor to devote her whole time temporarily to this work. Where the number of cases is large, one or more additional officers should be temporarily appointed.

Provision of Midwifery.—For the benefit of women who cannot afford to engage a midwife, the Board are prepared, where a local authority or a voluntary agency undertake, with the Board's approval, to provide the services of a competent midwife gratuitously or at less than ordinary fee, to make a grant equal to half the deficiency between the amount of the fee recovered and the ordinary fee of the district. Where in any district a competent midwife is not available, the Board are prepared to make a grant in aid of the maintenance of a midwife by the local authority or by a voluntary agency under a scheme approved by the Board. A local authority may pay or guarantee the salary of a competent midwife who is willing to practise in a district in which a midwife cannot make a sufficient income without such assistance. In a scattered district where there is difficulty in giving the nurse-midwife sufficient work, it is desirable that midwifery and district nursing should be combined; and it is often possible to arrange, where the nurse-midwife is suitably qualified, that she should also act as health visitor, school nurse, tuberculosis nurse, and mental deficiency visitor.

Provision of Doctors.—Where a local authority or a voluntary agency, with the Board's approval, provide the services of a doctor, when called in by a midwife for necessitous women, the Board are prepared to make a grant of half the fee paid to the doctor. A similar grant will be made for the services of a doctor in necessitous cases where a competent midwife is not available. A scale of fees must be submitted to the Board for approval.

Provision of Maternity Nurses.—The grant is available in aid of approved arrangements for providing the services of

a properly qualified maternity nurse where this assistance is needed, and where the woman cannot afford to pay for it.

MEDICAL ATTENDANCE AT A CENTRE.—Medical attendance should be provided at the Maternity and Child Welfare Centre, and it should be regular and uniform—*i.e.*, the same doctor should attend at stated intervals. The Board does not approve of a rota of doctors at a Centre.

HOSPITAL TREATMENT.—A grant in aid of hospital beds will, as a rule, be paid only to a local authority, and only in respect of maintenance expenditure on accommodation provided by the authority, or in respect of contributions made by them to a voluntary hospital for the right to use beds in that hospital. Information must be supplied to show that the accommodation for which a grant is claimed would not have been provided for the cases for which it has been used if a contribution from the local authority had not been available.

VOLUNTARY AGENCIES.—Grants will only be paid to voluntary agencies engaged in maternity and child welfare work when their work is satisfactory and is co-ordinated as far as practicable with the work of the local authority. Local authorities are empowered to contribute to the funds of a voluntary agency in consideration of their undertaking maternity and child welfare work, which is within the powers of the local authority. In such cases it is generally desirable that the local authorities should provide the health visiting staff. Where a voluntary agency provides a Centre, the Medical Officer of Health should exercise supervision over it, and arrangements should be made for the attendance of the health visitor at the consultations.

THE QUALIFICATIONS OF HEALTH VISITORS.

In a memorandum on Training of Health Visitors issued by the Ministry of Health in July, 1922, the Ministry now requires, in cases to which its sanction and the payment of a grant is desired, that a woman appointed as a Health Visitor should have one of the following qualifications:

(i.) The certificate prescribed by the Regulations of the Board of Education.

(ii.) Three years' training in a General Hospital, or full training

in a Children's Hospital, together with at least one of the following qualifications:

(*a*) The certificate of the Central Midwives Board,

(*b*) The certificate of a Sanitary Inspector,

(*c*) The certificate for Health Visitors of one of the bodies approved by the Local Government Board under the Health Visitors (London) Order, 1909—*i.e.*, the Royal Sanitary Institute, the Royal Institute of Public Health, the National Health Society, or the Battersea Polytechnic.

For the present the Ministry is prepared to dispense with the full qualifications referred to in (i.) and (ii.) in special cases where the woman has had previous experience of the duties of a Health Visitor under a local authority.

The Ministry is of opinion that the visiting of expectant mothers before confinement, and of infants during the first ten days after birth, should be undertaken by the midwife (where one has been engaged) rather than by the Health Visitor.

The Need of Ante-Natal Clinics.

The number of still-births notified under the Notification of Births Act, 1907, which should include all deliveries of children after the twenty-eighth week of pregnancy, is usually about 2·5 to 3·0 per cent. of the total births notified. It is probable, however, that many still-births between the seventh month and full term fail to be notified. Gynecologists assert that for every still-birth after the seventh month of pregnancy there are at least four abortions between conception and the seventh month, so that for every 100 children born alive some 14 or 15 have died *in utero*. It is thus seen that the fatality amongst the unborn is somewhat higher than the fatality of infants in the first twelve months of life.

It has been estimated that if all women were under skilled medical observation during pregnancy, about half the antenatal deaths that now take place could be prevented, and the number of infants born prematurely and of feeble constitution could be much reduced. About one-fourth of the children who die in the first year of life succumb during the first week. The deaths of the majority of these, and of the majority of those

who die within two months or more of birth, of atrophy, debility, and marasmus, are due to ante-natal conditions, which might have been controlled or remedied by ante-natal medical attention.

The importance of obtaining the sympathetic co-operation of midwives in ante-natal work is evidenced by the fact that from two-thirds to three-quarters of all the births in this country are attended by midwives.

Dr. Amand Routh gives the following as causes of ante-natal disease and death:—

1. PATERNAL CAUSES.—Syphilis and tuberculosis by direct infection of ovum. Diabetes, Bright's disease, plumbism, etc., inducing debility of the embryo.

2. MATERNAL CAUSES.—*Pathological:* Malnutrition, anæmia, acute specific and infectious diseases (including gonorrhœa), chronic diseases (including syphilis, tuberculosis, and plumbism), toxæmias, albuminuria, eclampsia. *Mechanical:* Retroversion of uterus, pelvic contractions, obstructing tumours, stenosis of cervix uteri and vagina, etc. *Miscellaneous:* Ante-partum hæmorrhages, placenta prævia, ectopic gestation, criminal abortions, etc.

3. FŒTAL CAUSES. — *Developmental:* Congenital defects. *Pathological:* Hydramnios, hydatiform degeneration of chorion, blood moles, toxæmias. *Mechanical:* Malpositions and malpresentations, malformations, etc.

In any scheme of ante-natal care there should be combined an ante-natal clinic, held weekly or fortnightly at a recognized centre by a skilled gynecologist, and home visiting of pregnant women by a trained health visitor. The inquiries made by the visitor should be entered on a Prematernity Card, and produced for the information of the doctor at the clinic. The card should give the number of previous pregnancies (if any) and details as to their nature and how they eventuated; the expected date of the approaching confinement; details of present pregnancy, and as to any danger signals (excessive vomiting, persistent headache, lessened flow of urine, discharges from vagina, constipation, impaired vision, swelling of face, hands, or feet); also advice given to patient under the heads of food, clothing, exercise and rest, medicines, care of breasts, preparations for labour, baby clothes, etc.

The patient's visit to the clinic should be recorded on the card, and the medical advice given or treatment recommended.

The health visitor, in such cases as may be required, should revisit the home to see that the medical instructions are being carried out, and that all proper steps are taken to prepare for the approaching confinement.

By such a system of ante-natal care it should be not only possible to reduce the death-roll of unborn infants and preserve the lives of many infants now born to die within a few weeks of birth, but it should also be possible to preserve the health of the mothers, to save them the exhaustion of long and complicated labours, and to restore them after confinement to such conditions of health as will enable them best to suckle their children and perform the necessary duties of motherhood. The Maternity Benefit of the National Health Insurance Acts should be supplemented by a Pregnancy Benefit, which would enable the poorer class of mothers to carry out the medical directions given them at the ante-natal clinics.

Under the National Insurance Act, 1920, it is provided that the sum of 40s. (Maternity Benefit) is payable to the wife, or widow, of an insured person, or to any woman who is herself insured, provided that these persons have been insured for twenty-six weeks. In addition, a married insured woman is entitled to sickness benefit for four weeks after confinement, at the rate of 12s. per week. Therefore, a lying-in woman may receive as much as £4 8s. in all when the above-mentioned conditions are complied with.

Infant Consultation Centre and Clinic.

This should comprise three rooms—one used as a waiting-room, one as a weighing-room for babies, and one for the doctor. The Centre should be situated in a district convenient of access foı the poorer class of mothers, and the consultations should be held in the afternoons weekly throughout the year. The physician should be an expert in the physiology, diseases, and hygiene of infancy and childhood, and should attend regularly. Records should be kept of the attendances, with the weights of the babies, and the advice and instructions given in each case. Treatment of simple ailments may be given on the spot, or the mother referred to a hospital, dispensary, or medical practitioner, as found desirable.

Health visitors should pay their first visits to newly born

infants ten days after birth, at which period the visits of the midwife usually cease. The mothers should be urged to bring the infants to the Consultation Centre regularly—once a fortnight or once a month, as may be considered necessary. Periodical visits should be paid by the health visitors to the homes of infants until they are a year old. Frequent visits are necessary, where the infant is not progressing satisfactorily, where the mother is inclined to be negligent, or where the infant does not attend regularly at the Centre.

After the first year of life, the family should be visited from time to time, to ascertain if the child is progressing satisfactorily, and the mother should be urged to bring the child to the Centre for medical inspection if its health is unsatisfactory. The visits may cease at the age of five years, or earlier if the child has been entered on a school register, and the records accumulated as to its condition of health at various ages should then be passed on, or made available for the school medical inspector.

By such a system as this many of the disabling illnesses of early childhood may be prevented, and the child enabled to begin its school life with the best prospects of deriving benefit from school education. The prevention of disease in infancy and early childhood does not in practice mean the survival of the unfit, but rather the survival of children, under conditions of healthy normal development, who are best fitted to form capable future citizens, to support the foundations of the national life.

Day Nurseries.—Dr. Reid has demonstrated statistically the evil that results from the prevailing practice in many manufacturing towns of mothers leaving their homes during the day to work in factories. Children are as a consequence deprived of their natural food and of the care of their natural guardians. An inquiry instituted by a Parliamentary Bills Committee tended to show that the amount of infant mortality attributable to the practice of married women engaging in factory work, may amount to 21 per cent. of the total. Two remedies are suggested in the report, one being the extension of the period of compulsory absence from work after confinement, required by the Factory Act, 1901, from one month to three; and the other, the establishment of day nurseries or crêches by local authorities, for which a small payment should be exacted from the parents.

Under the conditions of modern urban life many women of the poorer classes must be engaged in other than domestic

labour, and absent from their homes for many hours; and the wage earned by these expectant and young mothers is doubtless of considerable value to the health of both mother and child in the food which it provides; and the disadvantages of such work at such times is therefore to some extent compensated for. This circumstance has to be borne in mind in connection with the suggestion of the prohibition of the employment of women within four weeks of confinement. For such women a cheap and well-administered crêche is a great boon; and it has been suggested that such institutions might be utilized by the elder school girls for training purposes in the management of infants.

The advantages of a crêche are that it affords a healthy abode for the infants during the absence of their parents from home, skilled feeding for the infants, and facilities for detecting the onset of illnesses when the crêche is under skilled supervision. The obvious drawbacks are that the child is exposed to cold while bringing it to the crêche and taking it away at night, and the risk of the spread of communicable diseases among the children.

Homes for the reception of pregnant working women have been for some years in existence in France. The experience of these homes shows that cessation from labour for a fortnight or a month preceding confinement, renders the pregnancy more likely to proceed to the normal term, and the infants in consequence are stronger and more fully developed at birth.

The "Consultations des Nourrissons" were founded by the late Professor Budin, and are now to be seen in France in considerable numbers. The scheme included advice, and in some cases assistance, to pregnant women, and advice and assistance to mothers with reference to the feeding of the infant. The mother is always encouraged to suckle the child for the full period; but those who are dependent partially or entirely upon artificial feeding are provided with sterilized milk, and the infant's weight is weekly registered. These mothers' clinics have been aptly called "Ecoles des Mères." A somewhat similar provision first founded at Fécamp in 1894 was termed the "Goût de Lait." The late Dr. J. F. J. Sykes and others have drawn attention to the increased immaturity of infants at birth during recent years, and to the fact that this diminished viability cannot be due to artificial feeding, but to the ante-natal condition of the mother; and, as Dr. Sykes pointed out, the fundamental idea of

the Home for Mothers provided in the Borough of St. Pancras, London, is that the pre-natal conditions of the mother are of primary concern, and of the post-natal conditions the mother should receive the first consideration; that mothers must, wherever it is possible, be prevailed upon to suckle their infants; and that in order to make the provision really effective, the co-operation of medical practitioners, medical attendants at provident dispensaries, the medical staffs of hospitals, midwives, nurses, district visitors, and the philanthropic public, must be secured.

CHAPTER XI

SCHOOL HYGIENE

1. Notes upon the School Premises.

In selecting the site for a school, regard should be paid to a central position and the facilities of access by the scholars. A noisy site is very undesirable, and, if a quiet site cannot be obtained, the building should be set back at least 60 feet from the street. The ideal site faces south or south-east, has a good subsoil, is fairly level, and is on slightly elevated ground.

In *planning* a school building the schoolrooms must be the prime consideration; the building should be a number of school-

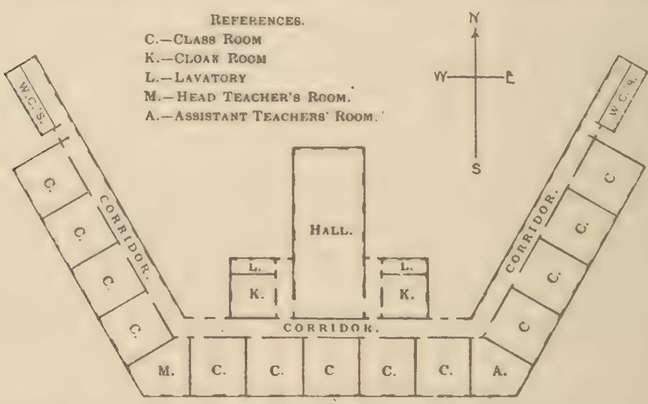


Fig. 86.—Diagrammatic Representation of E-shaped School.

rooms properly disposed, and not a whole cut up into schoolrooms, whose size and arrangement are dependent upon the size and shape of the building (E. R. Shaw). If possible, the rule should be observed that lines drawn from the bottom of the walls of the building to the tops of the nearest adjacent buildings should not make a greater angle than 30° with the horizon. It is desirable that the building should never exceed two storeys in height, and the main corridors of halls should be

at least 10 feet in width and well lighted. A corridor or pavilion plan of buildings is preferable to the type in which the classrooms are grouped around a central hall, for the reasons that in the former case the ventilation, by natural means, is much more

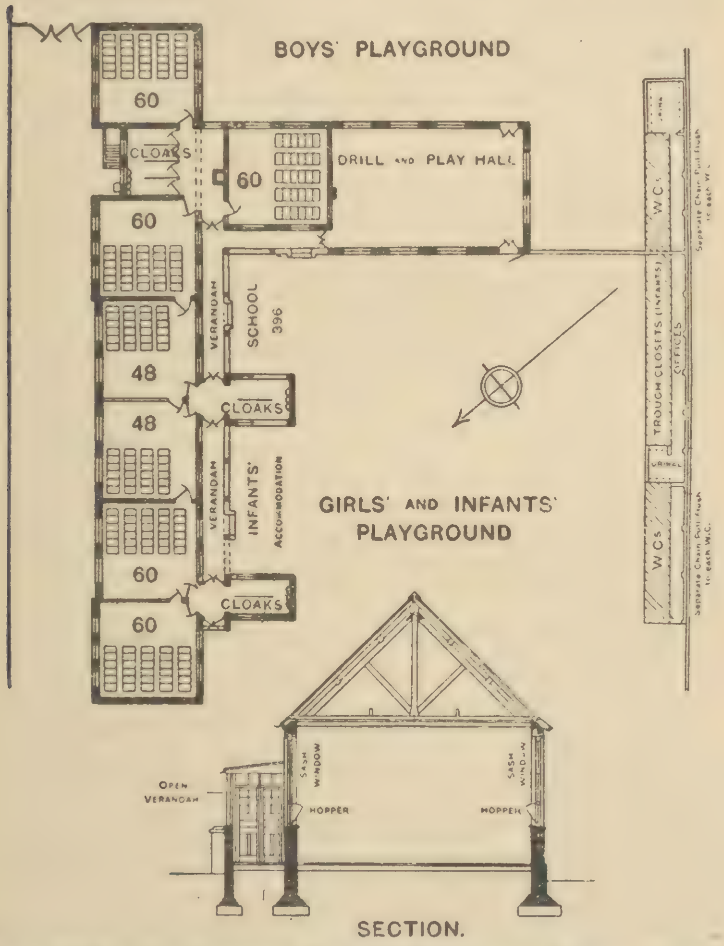


FIG. 87.—THE STAFFORDSHIRE TYPE OF ELEMENTARY SCHOOL. GROUND PLAN OF INFANTS' SCHOOL, WITH DRILL AND PLAY HALL. ALSO SECTION OF CLASSROOM.

efficient, and the occasional distractions in the classrooms, from the use of the hall, are avoided.

The satisfactory *lighting* of school classrooms demands an aspect, etc., which will ensure sufficient light in every part of

such room, even on dull days. Whereas the predominant light should fall on the scholar's left, it is not desirable that all the light should do so, or the scholars may cast shadows on the desks of those working immediately on their right. It is important that there should be no glare from the light; with the object of avoiding this, the windows should be fitted with outside linen shades to cut off sunshine, and in the case of artificial light the globes should be glazed and capable of absorbing excess of ultra-violet rays. Occasionally ordinary window illumination has to be supplemented by prism panes and reflectors, the latter being placed at an angle of 35°. For artificial illumination either electric inverted lamps or incandescent inverted gas-burners should be employed. These lights should be placed at a height of about 6 feet from the floor and at intervals of about 6 feet apart, measuring from the first light, which should be placed a little to the left of the first seat in the first row facing the teacher. A sufficiently good test of illumination would be the power of an individual with average vision to read *small pica*, with ease and comfort, at a distance of 12 inches from the eyes. The generally accepted standard for artificial illumination is at least 10 to 15 candle metres on desks, and this would not represent more than one-third of the usual daylight standard. (A candle metre represents the light from a standard sperm candle at a distance of 1 metre.)

The area of the windows, clear of sash frames, should be from one-fourth to one-sixth of the floor space of the room, depending on the aspect of the room—one-fourth for rooms facing north, and one-sixth for rooms facing south. The windows should reach as high as the ceiling of the room, and open directly into the external air, and the intervals between them should be as small as possible. The height of the sills from the floor should never be less than 4 feet. The defective lighting in school-rooms is one of the chief causes of short-sight; the child, not being able to read its book when placed at the proper distance (at least 12 inches) from its face, stoops over the desk to lessen the distance; the eyes converge when brought too near the object, and the muscular strain thus induced leads to a yielding of the plastic eyeball, with an elongation of its antero-posterior axis, and myopia results; *i.e.*, the image of the object seen forms in front of the retina (unless the object itself is very close to the eyes), and is blurred and indistinct. Imperfect lighting also

leads to the use of artificial light, which often adds to the vitiation of the atmosphere.

Suitable arrangements for the *warming* of school classrooms must be provided to maintain a temperature of 65° F. in the infant department, and one from 56° to 60° F. in classrooms for the older children; this must be done while considerable quantities of fresh air are being admitted, and never at the expense of fresh air. It may be taken for granted that if rooms are not properly warmed they will not in practice be properly ventilated. For warming purposes, the best method is the low-pressure hot-water system, with sufficient radiators and pipes. Roughly, from 12 to 16 feet of low-pressure piping is necessary for every 1,000 cubic feet, in classrooms; and 18 feet should be provided in infant departments and in rooms at the end of a circuit. The ventilating fire-grates constitute the next best method of warming in small classrooms; two smaller grates should be provided rather than one, wherever this is practicable. A good expedient is to provide a fireplace that has a boiler immediately behind it which supplies hot water to a system of pipes leading from it around the classroom, through radiators, and back again to the boiler. Slow combustion stoves take up valuable space, and are less satisfactory. The walls and furniture of classrooms should always be warmed to about 60° F. before the children enter.

Every classroom should have a thermometer, placed away from the fire, and at breathing level. Except in very small classrooms, fires *must* be supplemented by some other heating agency. Hot-water pipes should always be made to assist ventilation. Stoves are not desirable, but, when introduced, they should be ventilating stoves and provided with chimneys. The warming of corridors and lobbies is of great importance.

Some system of artificial *ventilation*, with a supply of warmed fresh air, is necessary for schoolrooms where the amount of cubic space per head is very limited. The English Education Department requirements are only 100 cubic feet of space per scholar and 10 square feet of floor space; 9 square feet for infants and 17 to 18 square feet in secondary schools. These are the minimum requirements; but even with double these amounts, adequate ventilation by natural means in cold weather would be productive of draught and a great lowering of temperature in the room. Dr. Newsholme is of opinion that good average requirements for

schools are, for each scholar, 150 cubic feet of space, 15 square feet of floor space, and 1,500 to 1,800 cubic feet of fresh air per hour.

The problem of the ventilation of many school classrooms is rendered a very difficult one from the circumstance that a series of rooms, considerably overcrowded, may be occupied almost continuously for as long as three hours. With the cubic space available, theoretically the air should be changed twelve times an hour, winter and summer alike, if it is to remain clean and fresh; meanwhile the temperature of the classroom has to be maintained at about 60° F. No natural agencies are sufficient under these circumstances. Even mechanical ventilation, providing previously warmed air, would be severely taxed. Short of mechanical ventilation, the situation demands (*a*) suitable provision for warming incoming air; (*b*) cross-ventilation of the classrooms through hopper windows in opposite external walls, and frequent occasions for flushing the rooms with fresh air, by opening all windows. The hoppers should be provided to the lower parts of the windows, not to the upper. The plenum method of ventilating school premises does not often prove a success, and the object lesson of permanently closed windows is a bad one for the children.

Educational results are in no small measure dependent upon the air results, and insufficient air renewal in school classrooms is an important item in determining school fatigue. The mental and physical depression caused by the insufficient air renewal cannot be explained by the increase in carbonic acid.

In 1906 Dr. James Kerr reported to the London County Council (as the Education Authority for the County of London) upon the relation of the classroom atmosphere to the working efficiency of school children. The following tests were adopted: The number of simple addition and subtraction sums that could be worked in five minutes; and in order to assess correct judgment, the estimation of an angle copied from a blackboard. Numerous observations were made by Drs. Thomas, Stevenson, Hogarth, and Brincker in which the four chief air factors—viz., temperature, humidity, movement of air, and carbon dioxide—were associated in every combination and their effects studied. It was found that "in every case where boys were working under good air conditions the results showed a distinct improvement at the end of the session, whereas, when these air conditions were acknow-

ledged to be bad, the results were always inferior at the end of the session." Again, "if the results of similar mental tests set before and after a school session to a class of average children show a falling-off, or even an absence of improvement, in mental alertness and accuracy, it is just to conclude that some deteriorating influence has been at work. By methods of exclusion this was shown, in these observations, to be the atmospheric conditions." The observations appeared to warrant the following further conclusions: That carbon dioxide up to 0·35 per cent. exerts no appreciable effect on mental capacity; that temperatures above 65° F., independent of other air conditions, give rise to definite subjective symptoms (slackness and inattention in some, headache in others, and deterioration in mental work); that these symptoms do not appear at 65° F. if the air is kept in gentle movement by a fan in the room, and that at higher temperatures the above symptoms are ameliorated by such movements of the air; that with temperatures of 70° F. and over, other factors being normal, there are marked symptoms and very evident deterioration in mental alertness and accuracy; and that relative humidity does not affect the mental capacity of children at low temperatures (below 65° F.), but an increase of humidity appears to aggravate the effects of higher temperatures in reducing working capacity. Observations in America (Boston) confirm certain particulars of these findings.

The *walls* of a schoolroom should preferably be painted or distempered, so that they can be washed, and any colouring should be pale and subdued (a soft greenish-grey is recommended); unnecessary projections (cornices, etc.) which can harbour dust should be avoided.

The best *floors* are made of hard wood in narrow planks, with dovetailed or matched joints; these may be beeswaxed and polished at intervals, and should always be swept daily.

All *staircases* should be at least 5 feet wide and fireproof, and faced at the ground floor by a wide door, opening outwards towards the street.

Seats and Desks should be arranged parallel with one another, but at right angles with the windows. To avoid shadows when writing, the scholars should sit with the left hand nearest the main windows, so that the chief illumination may be from the left front. There is then plenty of light on the objects on the desk, but the rays are not reflected directly into the eyes of the scholars,

as they are in front illumination with desks facing the windows. If the predominant light comes from the scholar's right, then the shadow of his hand, while writing, falls upon the paper.

Desks should be from 15 to 18 inches broad, and should slope at an angle of about 15° for writing and 45° for reading. The height of the seat from the ground should equal the length of the scholar's legs from sole of foot to knee. The distance of the front of the seat from a perpendicular line let fall from the edge of the desk should never exceed 1 inch. The perpendicular distance of the seat from the edge of the desk should be one-sixth of the scholar's height. The front to back measurement of the seat should be two-thirds of the upper leg, and the front edge of the seat should be rounded. Seats and desks should be adjusted to the scholars twice yearly. The heights of scholars of the same age often vary as much as 10 inches. Girls grow most between 12 and 14; boys, between 14 and 16. There should be a straight back to the seat, with a curved pad or cushion to fit into and support the small of the back and loins to the level of the shoulder blades. The space, on a common seat, for each pupil, should equal 20 to 24 inches; there should be 10 inches between the rows of seats, and the rows should not extend to within 24 inches of the wall. From each seat one should be able to see the sky. There should be a small raised platform for the teacher. Single desks and seats are good, but extravagant of floor space. Dual seats and desks may be recommended. The Sheffield type, consisting of a continuous desk with six separate seats, is far preferable to a long common seat and desk.

For young children prolonged posture at desks is bad, and the lesson hours should be broken by frequent short intervals of play.

Blackboards should possess dull or matt surfaces; they must always be placed in a good light, and any matter shown upon them must be large and well spaced.

The *cloakrooms* must be capacious, specially heated to dry damp clothes, and ventilated. They should be entered from a corridor. Cloakrooms should be cross-ventilated, and, to favour air renewal, it is a good plan to put wire-netting in the upper panels of the doors. The provision should be in the proportion of about a cloakroom to every 120 scholars. The metal hanging-hooks for hats, etc., should be from 15 to 18 inches apart in the girls' cloakroom, and at least 9 inches apart in the boys' cloak-

room; and never more than two rows of hanging-pegs should be placed upon one stand. If pegs are arranged on both sides of a stand, a partition of fine wire-netting should be provided, so as to keep the articles on the two sides from touching. It is desirable to have a separate cloakroom for each classroom, and for the pegs to be numbered and scholars made to keep to their pegs.

Covered sheds should be provided for recreation when it rains; and if a space is unprocurable on the adjoining ground, a basement or a flat roof may be designed to meet the purposes of a covered playground. It is essential that the scholars should receive plenty of physical drill and exercise in the open air. Under a proper system of medical inspection, commencing physical defects can be promptly detected and remedied by appropriate exercises.

Suitable *closet and lavatory provision* for schools should provide a prompt and rapid removal of excreta, which should be inaccessible to the scholars after deposition, the whole installation being an object lesson of cleanliness and sanitary practice. The seats of water-closets should not exceed 14 inches in height for the older children, and from 11 to 12 inches for the youngest. Water-closet seats, urinal places, and lavatory basins should be provided in the proportion of at least five of each of these provisions to every 100 boy scholars; and with girls and infants the water-closet seats should amount to at least 7 per cent. of scholars. Generally speaking, there are too few lavatory basins and clean towels provided in our schools. In places where there is insufficient water for flushing urinals, a good cheap and lasting material for coating the surface which receives the urine is cement coated with a mixture of pitch and tar. In country schools, where water-closets are not practicable, privy pits should always be replaced by pails (as where privies exist the water supply is very frequently from adjacent wells), and earth-closets provided. After use, the earth is best put in a shallow trench, and covered over with 3 or 4 inches of soil, and the soil collected from this site should be stored in a drying-shed in small quantities prior to use.

The Bedfordshire system is capable of furnishing excellent results in country schools. Suitable earth (garden mould) is automatically supplied to the earth-closets by means of a seat-action arrangement, which liberates the appropriate amount of earth from a hopper situated above and behind the seat, whenever

a closet is used. About a two-months' supply of earth (calculated at $1\frac{1}{2}$ pounds per child) is required in the first instance. The hoppers are charged from a service passage in the rear of the seats; and the pails, when two-thirds full of compost, are removed by this passage, and their contents placed in small, shallow heaps upon the level cemented surface of an enclosed annexe, which has been previously covered with a layer of dry earth. The passage and the annexe are made fly-proof, and abundantly ventilated by means of louvred openings protected by wire gauze. The heaps of compost are lightly covered with more earth, and at intervals of a few days they are turned over so as to promote drying and admixture. After a few such turnings the material is spread out to a depth not exceeding 3 inches, and the paper is raked away and burnt *in situ*. In from one to two months (according to season and weather), the now dry compost is sifted through a sieve with a $\frac{1}{2}$-inch mesh; and this sifted material is heaped ready for use and fit to commence a fresh cycle. Any coarser pieces not readily broken up on the sieve may be buried.

In the latest type of system, the pails are abolished, the dejecta being deposited directly on to a paved and drained surface beneath the seats.

All these arrangements are calculated to prevent fly-breeding, to promote the action of the micro-organisms concerned in the resolution of fæcal matter, and to guard against offensive odours. In such a scheme of working the earth may be used over and over again for many years, with an increase rather than a deterioration of its efficiency, and with an almost complete absence of odour and of the fly nuisance and danger. It may be added that the method involves a minimum of labour.

One of the modern types of trough water-closet or latrine (*vide* p. 90) is sometimes used for schools, but the flushing provision must be adequate and systematically regulated. Separate closets with separate flushing cisterns are to be preferred. The closets must be entirely detached from the main school building.

All *dormitories* must be well lighted and ventilated, and at least 400 to 500 cubic feet of space should be allowed for each scholar.

Drinking Water.—Drinking cups used in common by most scholars may be a means of communicating disease, such as diphtheria. Many cups should, therefore, be supplied in place

of the one or two only which are generally provided. Arrangements should also be made so that the cups, after use, are continually exposed to flowing water (direct from the main, if possible) during play hours; and the cups should be well cleansed with wet sand at least twice a week. In the "Crystal Stream" drinking fountain no cups are necessary, the scholars directly taking water as it issues in weak upward jets from the fountain. Another method is to provide a circular basin, over which the water continuously flows into little cup depressions, from which the children may drink.

The school premises should provide the best possible hygienic environment for the scholars, and should present an object lesson of cleanliness, brightness, good taste, and of scrupulous regard for all sanitary demands.

The teacher is not concerned with such matters as the selection of site and the planning and construction of premises, but can always secure the best sanitary circumstances under the existing conditions, and often an improvement in respect of these conditions.

The effects and value of environment, in so far as the school-child is concerned, are of a twofold nature—viz., the physical and educational. The educational effect and value is capable of further subdivision into the educational effect upon the scholar of sanitary precept and practice, and the effect of the sanitary environment in favouring or otherwise the mental response, and thereby promoting the general educational results. Nothing is more disabling from the standpoint both of the teacher and the taught than foul air; and the effect of improving the atmospheric conditions is, in the classroom as in the workshop, to improve the quality and amount of the work performed.

Dirt should be reduced to a minimum, as by clean boots, clean scholars, clean clothes, and chalk-troughs to blackboards. All dirt-harbouring arrangements in classrooms should be reduced to a minimum—viz., cupboards, shelves, projections (cornices, etc.), platforms, hangings. All decorations on walls should be easily cleanable, and the floors and walls washable.

At the end of the school-day doors and windows should be opened, and the floors swept with a damp broom, or after application of wet sawdust; the cloakrooms, corridors, etc., to be included.

Frequent cleansing and disinfecting precautions are more

particularly called for in the infant departments; and in such departments, upon every Saturday, the floors, seats, desks, tables, and window-sills of classrooms, the surfaces of cloakrooms (including hat-pegs), and the floors of halls and passages, should receive a liberal application of hot water containing washing soda, and good yellow soap; finally, the washed surfaces may be sprayed with a little disinfectant solution. In making the choice of a disinfectant, one of the coal-tar series (izal, cyllin, etc.) may be selected, which is capable of forming a fine and homogeneous emulsion with water, and possesses a carbolic acid coefficient of at least 12; and if all vertical surfaces are sprayed with a sufficiently fine spray from below upwards, there is no risk of any unsightly stains remaining upon walls, etc. It is hardly necessary to add that all drinking vessels should also be specially cleansed once a week.

Upon alternate Saturdays the whole school premises should be similarly treated; and upon every fourth Saturday some additional items should be included in the scheme. Then all woodwork to a height of 6 or 7 feet should be scrubbed; all cupboards, ventilating openings, bookcases, and storerooms should be cleansed and sprayed; and maps, books, etc., should be taken outside the buildings and well dusted.

Dustless oils, if used fresh and applied to floor surfaces for several days before these surfaces are used, tend to prevent dust from rising, and may be recommended. The material costs about five shillings a gallon, and requires to be applied just before the commencement of each school term.

All waste matters upon school premises should be burnt, when possible, and failing this, promptly deposited in covered, movable, metal dustbins, placed out of reach of the scholars.

The *Disinfection of School Premises* should generally be performed by the Sanitary Authority, or under their directions.

2. Notes upon the School Child.

Under the Elementary Education Acts, 1876, 1899, children from 5 to 14 years of age must attend school; and under the Elementary Education (Defective and Epileptic Children), and (Blind and Deaf Children) Act, 1899 and 1893, parents must cause abnormal children to receive education up to 16 years of age.

The NERVOUS SYSTEM contains the machine of the Mind; it receives and interprets various sense impressions, regulates all the vital functions of the body, and controls or commands the muscular system. It should therefore be the cardinal study and concern of the teacher.

Wrong or slovenly acts, at first under conscious control, may in time develop into subconscious or unconscious *habits*. Hence the necessity for a careful attention to the formation of good habits of thought and of action, and for the early correction of bad habits or tendencies.

Even in health, children differ greatly; and in mental education the special needs of the individual must be studied. Permanent injury results from premature or excessive stimulation of the brain faculties, by impairing the whole nervous system, and the general health and development of the brain and body suffer as a consequence; it is therefore opposed to all the objects of education.

Mental Fatigue is less due to overwork than to wrong work at the wrong time and in the wrong way. It is accompanied by a slight increase in the cardiac pulsations and blood pressure; by depressed muscular force and lessened cutaneous sensibility. It may be measured by the ergograph, the æsthesiometer, and the quality of any set work (such as sums, writing to dictation, etc.). No class should last longer than forty-five minutes.

The Symptoms of Brain Fatigue and "Over-pressure" are: (*a*) *Normal and Transient.*—Yawning, lassitude, wandering eyes and inattention, drowsiness, fidgetiness, slow or faulty response to words of command and questions, head balance impaired, little or purposeless movement.

(*b*) *Continued and Abnormal* (*Over-pressure*).—Nerve signs: Irregular muscular movements—chiefly of fingers, eyes, and mouth; knitting of eyebrows and overaction of frontal muscles; defective muscular balance of the body (especially of the head); excessive reflex actions; the abnormal position of the hand when held out in front at a word of command (slight drooping of thumb and fingers); stuttering; restlessness and frequent twisting of body and neck. Impairment of the delicacy of touch perception. Irritability, grumbling, and excessive sensitiveness to reproof. Facial expression of exhaustion or anxiety; open mouth; lower eyelids baggy and relaxed. Languor, listlessness, headache, speedy fatigue, dulness or apparent stupidity; slow or inaccurate

response to questions or commands; excessive drowsiness or wakefulness; night terrors; walking in sleep; poor bodily development and impaired health (pallor, failure of appetite, poor digestion, feeble circulation, etc.). It is a predisposing factor to chorea, hysteria, and epilepsy.

Scholars Especially Liable to Suffer from Over-pressure: Delicate nervous children (apt to be irritable, passionate, and emotional); constitutionally weak children; anæmic, badly fed, rapidly growing, excitable and mentally precocious children. Those exposed to bad air or bad conditions of study; bad teaching and unhealthy home conditions; too little sleep and recreation; defects of sight, hearing, etc.; excessive strain of vision, etc.; the period of puberty.

The Prevention of Brain Fatigue: A Hygienic Time-Table is of prime importance—one which economizes the brain energy and directs it aright:—Short lessons, with length varying with the subject (no lesson should take more than three-quarters of an hour); a proper sequence and variation of subjects; proper regard to stage of development of the scholars and the immaturity and instability of the nervous system in the early years of school life; sufficient intervals for rest, recreation, physical exercise, and food. Fresh air; quiet classrooms; strict limitation of the subjects selected for, and the duration of, home-lessons. Home-work not to take more than one hour; revision work only; and never before 10 years of age. An observant teacher will see the first signs before exhaustion results, and will discover when imperfections of vision and hearing are causing strain and brain fatigue.

Apparent Dulness may be due to defects of hearing or vision; poor nutrition or injudicious teaching; illness; bad air; insufficient recreation and sleep (child-labour).

Mentally Defective children make poor progress in studies, and show unusual peculiarities of temperament and of moral perception.

In the term "mentally defectives" those who are merely dull and backward are not included. The former are incapable of benefiting much from ordinary school education; and, in their own interests and in the interests of other scholars, they should be early removed to special institutions, where they may be trained in manual work and kept under permanent observation and control.

Children suffering from word-blindness, word-deafness, and moral imbecility also demand special provision for education.

Chorea (St. Vitus's Dance).—Occurs chiefly in girls between 7 and 14. Onset gradual. Constant twitchings of body, face, limbs, or hands. Things are dropped because of impaired control and power of muscles. The child is generally below normal weight.

Hysteria.—Especially in emotional girls at age of puberty Emotional outbursts; morbid sensations (ball in throat, etc.); paralytic symptoms, etc. Fits are of gradual onset, with sobs, laughter or other emotional display, then with a scream the girl falls violently convulsed and apparently insensible; she rarely injures herself, and never bites the tongue.

Epilepsy.—Momentary palsy of face, then sudden unconsciousness, stiffening of body, biting of tongue, hands clenched, and convulsive movements of limbs and muscles of face (face distorted and blue from congestion). The fit is followed by drowsiness.

The physiological necessity for adequate *rest and recreation* and good physical training must not be ignored. These reduce the number of cases with signs of brain disorderliness and the number of dull children.

The importance of quality and quantity of sleep as affecting the working capacity of the brain cannot be exaggerated.

Sleep is necessary for the growth and repair of both physical and mental tissues, and deficient sleep is a great factor in mental dulness and malnutrition.

The quantity of sleep which is desirable during school ages is as follows:—

Years of Age.	Hours of Sleep.
4–8	12
9–12	11
12–14	9–10
14–20	9

A well-ventilated bedroom (open windows), absolute quiet, darkness, and a warm bed, favour sound and refreshing sleep.

The *development of the nervous system* of a child is one of great importance from the educational standpoint. In childhood, especially from 3 to 10 years of age, the nervous system is unstable, rapidly developing and easily tired. Since mind and body act and react upon each other, the body suffers if excessive

demands are made upon the brain, and the brain suffers if excessive demands are made upon the body. The coarse large movements of early childhood slowly become finer with the gradual development of the complex co-ordinations necessary for fine movements. Thus, up to 5 years of age a child should be educated through the senses and its activities; then the memory should be developed, and good habits and training cultivated. After 10 years of age the child's reasoning powers and imagination develop. Probably the chief period of character formation is from 5 to 8.

Psychologically, it is to be remembered that the young child is very imitative, craves for approval, and seeks to emulate; it is naturally curious, and its activities are incessant; these latter must be controlled and directed to useful educational ends—physical, moral, and mental. Any tendency to such defects as selfishness and falsehood must be early checked, always remembering that the will to do comes first, and inhibitory powers (the will not to do) later; hence the truth in the old pedagogical maxim, "Don't say 'don't.'"

VISION.—In children the eye is relatively short from before backwards, and the child has to compensate for this by muscular effort, which involves eye fatigue and nervous strain; moreover, the still developing nerves of the retina are easily tired. In early life the eyes are soft and plastic, and readily yield to conditions favouring defective vision.

The eyesight of at least 20 per cent. of scholars is defective, and in 10 per cent. it is seriously defective. Affections of vision are, therefore, among the most common hindrances to school work.

The strain of correction where vision is faulty leads to eye fatigue, which causes brain fatigue and diminished perception; furthermore, brain fatigue leads to general constitutional results.

The causes of eyestrain are: Too continuous eye-work, and a bad time-table; fine and indistinct work, and work brought too near the eyes; bad or faulty lighting of room; bad posture in reading and writing. Predisposing causes are badly ventilated and overheated rooms, debility and poor nutrition of scholar.

The printing, etc., of school books is of great importance. "Double Pica" should be selected for infants, and "pica leaded" for older school children.

The *Symptoms of Defective Vision* are: Headache, generally frontal, worse at night and relieved by sleep; a sense of fulness in head; redness of eyeballs and eyelids; watering of eyes; blinking; partial closing of eyes when looking at distant objects; frequent rubbing of eyes; heat and pain in eyes; dizziness, and sometimes nausea or even vomiting; squint; irritability, neuralgia, and impaired general health; books held within 12 inches of the eyes; confusion of letters—especially *h* and *b*, *e* and *c*; inattention and apparent stupidity.

Short-Sight (myopia) is rare before 8 years of age, and increases greatly as we pass from lower to higher grades at school; hence an illustration of the injurious effect of school life upon the scholars' eyesight. This condition is due to the "long eye" with the too distant retina; and hence concave lenses are needed.

It is most liable to develop in delicate children with poor muscular and nervous tone, and especially when parents are myopic. Convalescence from acute fevers, bad air, bad habits, night work, overheated rooms, favour the condition. Prominent eyes with large pupils suggest myopia.

Bad posture during reading and writing may cause myopia, and myopia may cause bad posture.

Long-Sight (Hypermetropia).—This condition is due to the "short eye" with the too near retina; and hence convex lenses are needed. This is the most common eye defect in young children. Eyestrain is continuous in school, and there is no relief by bringing objects nearer, as in short-sight. Small deep-set eyes, with contracted pupils, and red, watery eyes, suggest long-sight.

Astigmatism.—Blurred images and indistinct vision at any distance, due to eyeball (especially the cornea) being asymmetrical, and thus part of object is seen out of focus. The condition is generally congenital, and often exists with long- or short-sight. The child who peers or who looks obliquely probably has astigmatism.

Squint is generally due to the focussing power of the two eyes being unequal and to overstrain of certain eye muscles.

Squint usually comes on at about 3 years of age; and the convergent squint of children is generally associated with long-sight. A squinting eye is a non-seeing eye, and early treatment is necessary to prevent serious complications.

Glasses do not weaken the eyes, but strengthen them; they

conserve the sight, prevent headache, etc., and prevent squints, or may even cure them.

Colour-Blindness.—Most colour-blind people cannot tell red from green, and call them shades of the same colour.

Ophthalmia and Conjunctivitis.—Redness of eyes, crusts on margins of lids, with loss of eyelashes; extreme sensitiveness to light; excessive watering of eyes; formation and discharge of yellow matter.

Habit-Spasm.—This is due to the spasmodic contraction of the ciliary muscle in the direction of the muscular movement which has predominated for some time. It is a visual "cramp," most frequently observed in nervous girls of over 11 years of age, and rest, fresh air, and good feeding are demanded.

Congenital Word-Blindness.—In this condition the visual recognition by the eye-brain is abnormally slow or congenitally defective. The scholar has no visual memory for words or letters, or the brain acts slowly in interpreting such objects as letters. The condition causes dulness in learning to read and write.

The vision is tested by Snellen's cards, which contain letters of diminishing size from above downwards. By these cards normal vision can read without effort the letters on the line marked 6, when the child stands at the standard distance of 6 metres, or 20 feet. Normal vision is expressed by putting 6 as a numerator, and the number opposite the smallest type which the child can read, at the standard distance of 6 metres, as the denominator; hence normal vision is expressed as $\frac{6}{6}$. If, however, the child could only read the type of the line marked 12, its vision would be expressed as $\frac{6}{12}$, or one-half of normal. $\frac{6}{12}$ is often advocated as the standard for the elementary school child; and it is only when the vision is worse than this—say one-third normal, or less—that the child is measured for spectacles. Vision should be tested on admission to school, and once during each year of school attendance, assuming the child to be over 6 years of age and capable of interpreting what it sees. Any facial distortion or oblique or advanced position of the eye must be noted; one eye should be tested at a time, and if the child already wears glasses, the test should be applied with the glasses on.

Colour-blindness may be sufficiently tested for school purposes by means of a few skeins of bright green wool, mixed with a mass of confusion colours among which reds figure prominently. If

the child can pick out all the skeins which match a pale green skein, vision may be pronounced normal in this respect.

To conserve vision, *school books* should meet the following requirements: Sufficient thickness of paper; type large, clean cut, thick-faced, and well-defined; letters and lines well spaced, and good margins to the pages; ink black; paper white or tinted yellow; no type allowed which necessitates the holding of the book at a less distance than 12 inches. Best types are "double pica" for very young children, "pica leaded" for children 6 to 11 years, and "small pica leaded" for the older children; small type annotations disallowed; the lines of the school book not to exceed 4 inches in length. It is desirable that a standard of book production for school purposes should be established. In school illustrations placed upon walls there should be a bold, firm treatment of a few objects only.

HEARING.—Generally from 12 to 20 per cent. of scholars are defective in their hearing. The *Signs of Defective Hearing and Ear Disease* are: The child misses spoken words or directions; strained attention in class; inattention and apparent stupidity; early exhaustion from lessons; mouth-breathing; earache; headache; discharges from ears; giddiness; impaired general health.

The *Causes of Defective Hearing* are: Adenoids and enlarged tonsils; inflammation or abscess in the middle ear from inflammation or disease of nose or throat (catarrh, measles, scarlet fever, diphtheria, etc.); wax in ears. It is found that among school children who are deaf-mutes some 60 per cent. were born deaf.

On admission to school the hearing should be tested, and subsequently once a year. The testing is always difficult, and many tests have been suggested, such as the whisper test, the stop-watch test, the tuning-fork test, the audiometer, and acumeter. Probably the best test is the forced expiratory whisper (stage whisper) at the standard distance of 20 feet. The child must not see the lips, and so should be placed with the back to the teacher; both ears should be separately tested, the child being made to repeat numbers. In some noisy classrooms it is necessary to examine several apparently normal children, and get these to establish the standard distance for the test in that particular room.

Through the auditory word-centre the child grows to associate

words with ideas; then the motor word-centre (for speech) develops, and the two becoming linked up, the child imitates the sounds that it hears. The visual word-centre develops later, and becomes linked up with the auditory and motor word-centres for speaking and writing; and then by memory (the storage of impressions) the child can name and write pointed or heard words, and recall the object to which the word relates. A child suffering from word-blindness has not this visual word-centre properly developed, and one suffering from word-deafness has a defect in the auditory word-centre; but vision and hearing in all other respects may be normal.

Early attention to defects of sight and hearing will either lead to a cure or will prevent matters going from bad to worse, and thus save the scholars from grave educational losses and disabilities in after life.

Exercise.—The muscles contain in their substance about one-quarter of the blood of the whole body; their action promotes the circulation of the blood, and hence plays an important part in promoting the general nutrition. During muscular exercise the force and frequency of the heart's action are increased; the respirations are more frequent and deep; and the functional activity of the organs of digestion and excretion (skin, kidneys, and bowels) is increased. The development of the nervous and muscular systems are interdependent, and both are promoted by muscular activity. Hence muscular exercise promotes an active circulation of the blood generally throughout the body; develops the muscles and improves the carriage and symmetry of the body; trains, through the nervous system, the action of the muscles and the "muscular sense"; promotes the symmetrical development of the brain, and healthy and vigorous brain power; and generally improves body nutrition and maintains the body functions in health.

Furthermore, physical exercises at school counteract the harmful tendencies of bad posture, and reduce the number of cases of nervous disturbance among scholars. They can be made to correct faulty and defective conditions in the scholar's development, and also any acquired bad habits of posture or deportment; to provide a profitable diversion from brain work; to aid in school discipline and develop qualities of alertness, decision, and activity.

All exercise should be taken in the open air when possible,

and when under cover, the conditions should be made to approximate to open-air conditions as much as possible; all clothing should be light and loose; boots must not be stiff and tight round the ankles; flannel or woollen garments should be worn next to the skin; excessive fatigue from too violent and prolonged exertion should always be avoided, as otherwise too great a strain is thrown upon the heart; only gentle exercise should be taken directly after a meal. Physical exercises should be graduated to suit the ages of the scholars; sickly and deformed children, convalescents from diphtheria, etc., and those who have walked long distances to school, require special consideration and specially selected exercises; the exercises must not be too exacting between the ages of 13 and 16, and in the case of rapidly growing and overgrown children; such faults as holding the breath, stooping or contracting the chest, and the uneven performance of the exercises, must be corrected; suitable precautions must be taken to avoid chills after exercise.

For scholars over 8 years of age the school curriculum should include a scheme of organized games, those being selected which are best calculated to develop the physical, mental, and moral qualities of the scholar. In addition, certain drill exercises are needed; and after 14 years of age gymnastics are desirable —especially when any particular group of muscles needs training or strengthening.

Better results are obtained from short daily exercises than from longer exercises at greater intervals.

Ling's Swedish system of exercises has for its object the harmonious development of the skeleton, the muscular system, and the internal organs. Each movement is required to be a brisk, deliberate, and forcible response to the word of command; and special apparatus is used, including wall-bars, vertical ladders, horizontal ladders, climbing ropes, rope ladders, horse, vaulting-box, etc.

Folk-dances are to be encouraged, inasmuch as they inspire a love of physical exercises, and develop neuro-muscular coordination, and are graceful accomplishments.

Reasonable facilities and equipment should be provided in all schools for games, play, dancing, and swimming, in addition to any formal gymnastic exercises.

On the subject of physical exercises the revised syllabus of

physical exercises for public elementary schools, issued by the Board of Education, may be very profitably consulted.

There is much to be said in favour of occasional five-minute "fresh-air drills" in school classrooms. To this end certain "health monitors," appointed each week, should be told to open all windows and doors, when a deep-breathing exercise is maintained for about two minutes. For the deep-breathing exercise the following orders are given: "Stand erect!" "Attention!" "Hands on hips!" "Shut mouths"! "Breathe in!" (slowly given), "Breathe out!" (slowly given). The "Breathe in!" and "Breathe out!" are repeated six times. After a few moments' pause, the exercise is repeated another six times. This is then followed by a smart physical drill of symmetrical arm movements for three minutes. During these exercises the scholar must stand erect, and the head must not be thrown back.

Posture and Deformity.—In early life the bones consist partly of cartilage or gristle, and therefore readily yield, but ossification is practically complete at 12 years of age; hence a child, under favouring conditions, may become deformed. A bad position, for instance, remaining uncorrected for some time, may in certain children lead to permanent deformity, which displaces and compresses important organs. The children who are most liable to such deformities are rickety, strumous, debilitated and overgrown children, with poor muscular tone; and especially such children between the ages of 9 and 14.

Rickety Children may generally be distinguished by their large heads and prominent foreheads, small stature, "pigeon-breasts," bow-legs, enlarged abdomens, and they may be knock-kneed or flat-footed and give evidence of poor nutrition.

Rickety children are generally to be found in the infants' department. It is important that they should not be allowed to stand too much and that bad posture should be corrected. Such children specially require regular physical exercises and fresh air.

Strumous Children are often beautiful children, with fair delicate skins; they are especially prone to glandular trouble and are often narrow-chested.

The causes of *Bad Posture* at school are: Too protracted work at desks—especially writing (faulty school programme); bad seats and desks; bad school books; bad lighting of classrooms; bad habits; too fine and too near work; short-sight; ill-health and bodily weakness.

The evil results follow if seats are too high, too low, too narrow, or too flat, and have no spinal support; f desks are too high, too low, too narrow, and have faulty slopes; if too great distance between seats and desks, or seats and desks too near. The seat and desk should be adjusted to each scholar at least twice a year.

The results of bad posture are: Compression of chest, and interference with free movements of the chest in respiration and with the circulation of the blood; interference with the functions of abdominal organs; round or uneven shoulders and lateral curvature of spine; bad habits of body carriage; early fatigue; short-sight and headache.

Spinal Curvature—Lateral.—Is especially prevalent in girls of about the age of puberty. First a drooping of one shoulder may be noted, and then the shoulders or hips (generally the right only) "grow out"; backache, lolling, and stooping occur; later the crooked spine is very evident. *Posterior.*—Common in weakly and rickety children; round shoulders result. *Angular.*—Due to disease (caries) of spine; cannot straighten back; pain on percussion. Spinal curvature leads to displacement and compression of important organs, and though generally preventable at school ages, is extremely difficult of cure.

With *Good Posture* the head is erect and poised directly above the spine, and the two shoulders, hips, and elbows are level; if sitting, the thighs are at right angles with the trunk and the fore legs are at right angles with the thighs. If seat and desk fit the scholar he *sits squarely* in this attitude, with his work in front of him; his posture is symmetrical, and therefore his muscles are acting equally and are well balanced, and this ensures a minimum of muscular effort and discomfort. Muscular effort is involved in standing, and to a less extent in sitting still.

The Respiration in children must be free from any obstruction—whether in the nose or throat, or from interference with free chest movements, as by tight clothing or bad posture.

The signs of obstruction to respiration in the nose and throat are: Open mouth; muffled nasal voice; often a vacant and unintelligent expression; snoring; frequent colds and nasal discharge; breathing not free and often noisy; mental dulness; deafness; cough; nostrils compressed and poorly developed (if long-standing); and if child rickety, often "pigeon-chested."

The value of deep-breathing exercises is very great, especially in the growing child. They assist the circulation of blood, and

develop the chest capacity; they are also of value in children with early adenoids and spinal curvature, or who stammer.

The advantages of cultivating a habit of nasal breathing are:—The individual is less liable to sore throats and consequent ear trouble; dust or dirt in the inspired air gets filtered off to a great extent in the nose, from which it can be dislodged without being either inhaled or swallowed; and the nasal secretion possesses some power of inhibiting the growth of micro-organisms which may be retained on the mucous membrane.

Nasal discharges may signify: Catarrh, influenza, measles, adenoids, diphtheria, scarlet fever, or ulceration or foreign body in the nose.

Breathing foul air for a short time may cause: Languor, mental dulness, drowsiness, yawning, headache, faintness, nausea, and even vomiting; but breathing foul air day after day gives rise to serious and lasting consequences, including: Debilitation; loss of tone and vitality, and therefore poorness of appetite and impaired digestion; increased liability to infectious disease; throat and lung complaints and consumption; anæmia or poorness of blood; indications of impure blood, in bad complexion, skin eruptions, etc. It is also favourable to rickets.

By the Circulation of the Blood the following objects are achieved:

Food and oxygen are conveyed to the tissues for their nourishment, growth, and repair; the heat (which is generated in the muscles and the glands) is distributed over the body; and waste matters are carried from the tissues to the excretory organs.

The following symptoms in scholars probably indicate some departure from the normal in either the composition of the blood or the heart's action: Extreme pallor—especially of lips, gums, or the inside of eyelids (anæmia); languor; irritability; faintness; disinclination to play and breathlessness on exertion; emaciation; coldness of extremities; palpitation or pain over region of heart; blueness of nose, ears, or finger-tips.

Children with poor blood and defective circulatory systems are impaired mentally and physically. Their special needs call for some reduction in the mental and physical work demanded of normal scholars; suitable exercises (including deep-breathing exercises) will aid the circulation; but to maintain the blood good in quality and quantity proper food and abundance of fresh air are necessary. Bad feeding and bad living predispose

to *scurvy* and *purpura*—conditions which are characterized by hæmorrhages about the body.

The causes of Enlargement of the Lymphatic Glands are: Pediculi, wounds, sores and eruptions on skin or scalp; throat or ear trouble; carious teeth; scrofula or struma.

Enlarged lymphatic glands may be observed or felt up the sides of the neck (cervical), at the upper and back part of the neck (occipital), in the groins (inguinal), and immediately above the internal condyles of the humerus.

It is important to keep The Skin clean. Dirt impedes the important work of the skin and throws extra work upon other organs; it favours skin blemishes (blackheads, pimples, etc.), boils, abscesses, and the harbouring of parasites and germs of disease.

It is most important to develop cleanly habits in school children. The hair, face, and hands should always be clean, and the nails kept short. A weekly wash in hot water and a weekly change of underclothing are necessary to these ends.

Warm *baths* cleanse the skin and thus promote its healthy functions. Cold baths have a stimulating and tonic effect and reduce liability to catch colds. Swimming baths provide physical exercise, promote health, and afford opportunities of acquiring a useful accomplishment. A bathman or instructor should always be present.

Warm baths should be from 95° to 100° F. Hot, 105° to 110° F. Cold, 55° to 60° F. Swimming baths, about 70° F.

For schools the advantages of shower baths over slipper baths are: Fresh clean water constantly applied; more economical of time; cheaper; danger of infection reduced; more stimulating. A weekly shower bath (5 to 10 minutes) with soap and warm water, at about 90° F., is desirable.

The benefits of school baths as testified by school teachers and doctors are: Greater cleanliness of scholars' underclothing; reduction in skin diseases and vermin; increased self-respect of scholars; good moral influence on homes; better school work claimed by some.

It is of great importance to keep the Hair and Nails clean. The head-louse (*Pediculus capitis*) is a greyish-white insect, the female laying numerous eggs (nits), which are attached to the shafts of the hair, usually near the skin, by a gluey substance. The embryos in the nits take some 8 to 10 days to incubate.

Much irritation is caused by lice, which suck blood after biting; and the consequent scratching causes sores and scabs. When there are *lice* (pediculi) and their eggs (nits) in the hair, the child is generally pale and poorly nourished, dirty and miserable; a peculiar dry look about the hair, and scratch marks on forehead or behind ears. Lice or nits will be seen more especially when the hair behind the ears is raised and examined, when the scalp is often dirty, with sore places upon it. (Nits are smoky-brown, oval, glistening bodies, and should be looked for about half an inch from the roots of hairs.)

Where there are sore places or scabs the hair should be cut short, and in the case of scabs a linseed or bread poultice should be applied. The head may be cleansed from lice by the application of carbolic or paraffin oil overnight, and a thorough washing of the head with soft soap and water the next morning, after which the hair should be combed thoroughly with a fine tooth-comb repeatedly dipped in vinegar. This treatment should be repeated daily, when the worst head should be completely freed of lice in the course of a week. The following method is even more expeditious in removing head-lice: The hair is wetted by a 10 per cent. solution of liquor potassæ, brushed on with a whalebone hair brush. Thereafter the hair is combed, strand by strand, with a special comb—the Sacker hygienic comb. This comb is made of thin blades of steel or brass riveted together, and allowing between the teeth only sufficient space for a hair to pass. The liquor potassæ seems to have the property of causing the nits to become less adherent to the hair, and perhaps also to swell. Where there is difficulty in keeping a child's head clean, the hair should be worn short. (For *Pediculus vestimenti*, *see* p. 293.)

Ringworm.—Is most common between 5 and 10 years of age. It gives rise to one or more circular patches on the top of the child's head; the patches are covered with fine white powdery scales, and the hairs on the part are dull and mostly broken off. The treatment is difficult, and should be under medical direction.

Ringworm of the scalp is often spread by the caps of scholars; and this is one of the reasons why each child should have a numbered peg in the cloakroom and children should never exchange caps. It is difficult to tell when a child has completely recovered from this disease, and children frequently return to school too soon. All cases should be regarded as infectious

when broken-off stumps of hair are to be observed with a lens, and when such stumps, after removal and washing with ether and mounting for a few minutes in 10 per cent. potash solution, show spores of ringworm. Owing to the prolonged loss of education frequently entailed by this complaint, the educational authorities of some large cities have instituted special ringworm classes.

Ringworm of the body is most common on the face, side of neck, wrists and hands. Like ringworm of the scalp, it has a tendency to relapse, and to recover spontaneously at the end of the school period.

Impetigo Contagiosum.—This condition is distinguished by the presence of small, isolated, flat vesicles, generally first to be observed upon the face. The contents of the vesicles become milky and then purulent, and after a few days crusts or scabs form, in size from a split pea to a shilling. The face, scalp, hands, and arms may show these vesicles or scabs, and the condition is very prone to spread.

Favus.—In this condition, which is of rarer occurrence, orange-coloured crusts are to be observed on the scalp. The hair is brittle and dull, but not generally broken off short; and there is sometimes a mousy odour to be observed. It is generally seen in children of poor physique and low nutrition, and has not much tendency to spread. The treatment is very similar to that of ringworm.

Scabies or Itch.—In this complaint papules, pustules, excoriations, and fissures may be seen, more especially between the fingers. It is highly contagious, and demands prompt medical treatment. Many animals (including the dog and cat) suffer from this infection.

The CLOTHING of school children must be light and loose, so that it does not interfere with any natural function or movement, and it should be suitably distributed, so as to help to regulate the body temperature and to guard the system from chills.

Some common and easily corrected errors in the clothing of scholars relate to articles (such as tight collars or neck-bands, garters, stays, bodices, belts, braces, etc.) which by their pressure and constriction interfere with the circulation of the blood, the function of important organs, or free muscular movements; or which by their weight and ill-fit lead to deformity and awkward gait, such as heavy, ill-fitting boots.

FOOD is not only necessary to repair the wear of the tissues and to furnish heat and energy, but also for growth, in children.

School children require relatively more food than adults, because the food has to provide for the growth and the greater energy generally manifested. More especially is an abundance of good food necessary between 10 and 14 in girls, and 14 and 20 in boys.

Children of the ages below indicated require each day about the following amounts of water-free food constituents:

	Seven Years.	Ten Years.	Fourteen Years.
	oz.	oz.	oz.
Proteins	2·0	2·5	3·0
Fats	2·3	3·0	3·5
Carbo-hydrates	8·0	10·7	12·7
Mineral matter	0·7	0·8	0·8
	13·0	17·0	20·0

The symptoms of insufficient or wrong feeding are: Emaciation; deficient and flabby muscles; arrested growth; anæmia and sallow skin; looseness of bowels; lassitude, inattention, and mental dulness. The conditions known as Rickets or Scurvy are favoured by wrong feeding.

The Elementary Education (Provision of Meals) Act of 1906 enables Education Authorities to provide meals for school children, and to recover the cost from the parent, where possible. Where this provision is made at the schools, the teachers often assist in the cooking, and the elder girls are also encouraged to do so. The elder girls thus receive some of the instruction in simple cooking which is so necessary. This knowledge should be supplemented at continuation classes.

The rules for the diet of school children embrace a plain, wholesome, generous, nutritious, digestible, and varied fare, in which the amount of fresh meat allowed is limited, and fresh fruit, and baked and stewed fruit, should figure prominently. Raw apples and nuts, in addition to their nutritive value, are specially good for the teeth, more particularly at the end of a meal. The craving for sweet things should be met by supplying these in reasonable quantity at the end of a meal, after the appetite has been first satisfied.

Indigestion may arise from:—Bad teeth; improper mastica-

tion; irregular meals; tough and improper food; too frequent meals; food too hot; stewed tea; tight belts, stays, etc.

The good habits to be cultivated are:—Slow eating and good chewing; sufficient but not excessive food; regular meals; regular evacuations; the cleaning of the teeth.

Bad *teeth* may cause:—Pain and loss of rest; abscess and the swallowing of pus; enlarged glands and disfiguring scars; indigestion; fœtid breath; the habits of eating soft food and imperfectly masticating the food; grave constitutional conditions due to malnutrition. An abscess in connection with the temporary teeth may affect the development of the permanent teeth, and this may lead to imperfect mastication and defective articulation.

Quite 75 per cent. of the elementary school children of Great Britain give evidence of some degree of *dental caries*. When this condition is extensive the physical measurements are generally below the average. A tooth attacked with caries tends to promote the spread of the condition to other teeth. The preservation of the teeth is most important, and the conservative treatment should commence before 8. A yearly inspection of the teeth is therefore desirable, and the general use of tooth-brushes should be considered an essential act of cleanliness.

The value of ANTHROPOMETRICAL DATA is considerable. They enable us to learn whether growth is occurring at an exceptional rate at any age, and thus to make provision for the fact that the powers of mental and physical application are thereby reduced. In this connection it is important to note that exceptional growth is most liable to occur at or about puberty, and that growth in height without a corresponding increase in weight demands attention.

If growth is found to be deficient, it may indicate insufficient food or clothing, an excessive expenditure of energy in mental work, or the onset of some disease.

Good nurture promotes growth, and hence the height and weight are indications of nutrition. It is for this reason that children of the better classes are heavier and taller in both sexes than those of the poorer classes. Dr. Kerr has pointed out that dullards are generally below the mean height. The effects of heredity and home environment, underfeeding, neglect, and bad conditions of the mother's life (before and after birth) are very evident in the anthropometrical data of schools in the very poor districts of large cities.

The only anthropometrical data which it is found possible to obtain at present under the scheme of medical inspection of elementary school children, relate to the weight and height; but in many private schools chest measurements are also taken at the level of the nipple, both after emptying and expanding the lungs. The chief aims of anthropometrical observations are as follows:

1. To determine averages and standard deviations at different ages and for both sexes, having due regard to racial and environmental differences.

2. To correlate mental and physical growth, with a view to testing the efficiency of different systems of education and of indicating the amount of work that may advantageously be attempted at different ages, thereby minimizing the dangers of overpressure and adapting education to local needs.

3. To mark out the physically or mentally unfit for special educational treatment.

4. Where the deviation is abnormal in a number of individuals, a whole school, or a whole area, it would point to the necessity for special investigations of social conditions and environment.

The subjoined table shows that:

1. Boys are heavier than girls up to 12, but soon after 12 they lose their superiority for three years, regaining it by 16.

2. In boys the greatest increase occurs from about 14 to 16, in girls from about 12 to 15.

3. The rate of growth is irregular or interrupted. Boys are taller than girls up to 12, when girls pass them, and retain an advantage to nearly 15.

4. In boys the greatest annual increases are from 5 to 6 (almost 3 inches) and from 14 to 15 (about 3 inches)—viz., at the beginning and the end of elementary school education.

5. In girls the greatest annual increase is about 12.

6. In girls the annual increase is more uniform than in boys up to 14.

7. In girls growth begins to slow down between 12 and 13, and at 14½ girls have nearly completed their growth, while boys grow rapidly up to 19.

8. Girls of 13 and 14 are generally taller and heavier than boys of the same age.

Anthropometrical Measurements (Anthropometrical Committee of the British Association).

Age.	Average Weight (in pounds).				Average Height (in inches).			
	Boys.	Increase.	Girls.	Increase.	Boys.	Increase.	Girls.	Increase.
5	39·9	—	39·2	—	41·03	—	40·55	—
6	44·4	4·5	41·7	2·5	44·00	2·97	42·88	2·33
7	49·7	5·3	47·5	5·8	45·97	1·97	44·45	1·57
8	54·9	5·2	52·1	4·6	47·05	1·08	46·60	2·15
9	60·4	5·5	55·5	3·4	49·70	2·65	48·73	2·13
10	67·5	7·1	62·0	6·5	51·84	2·14	51·05	2·32
11	72·0	4·5	68·1	6·1	53·50	1·66	53·10	2·05
12	76·7	4·7	76·4	8·3	54·99	1·49	55·66	2·56
13	82·6	5·9	87·2	10·8	56·91	1·92	57·77	2·11
14	92·0	9·4	96·7	9·5	59·33	2·42	59·80	2·03
15	102·7	10·7	106·3	9·6	62·24	2·91	60·93	1·13
16	119·0	16·3	113·1	6·8	64·31	2·07	61·75	0·82

In addition to special schools for the blind, deaf and dumb, epileptic, and definitely feeble-minded children, some provision has been made during the past few years for the partially deaf, backward, physically defective, delicate, and tuberculous children, and children suffering from ophthalmia and ringworm. The establishment of open-air schools, playground classes, and open-air classrooms, are further new features in the educational scheme. But apart from certain classes of abnormal children who require special school training, there are many whose special needs can be met by an adaptation of the arrangements that obtain in ordinary public elementary schools.

The educational and hygienic needs of abnormal children are yearly receiving more attention in this country, and more special schools are being provided for certain abnormal children. At the special schools provided for physically deformed children, a prominent feature is made of handicraft instruction to the elder children. Girls are taught dressmaking, etc., and the boys carpentering and toy-making. It is found that tuberculosis is the cause of about 40 per cent. of such physical deformity; and that infantile paralysis causes 25 per cent., rickets 10 per cent.; the remaining 25 per cent. being due to a variety of conditions ranging from accidents to congenital deformity. After-care committees supervise such children. Such committees render valuable services to education authorities and parents by: interesting themselves in the general welfare of the children;

advising and helping parents, more especially with reference to after-employment; visiting the homes and stimulating cleanliness, decency, economy, etc.; promoting the medical treatment of children requiring it; assisting head teachers and school medical officers in determining the necessitous children requiring school meals; keeping in touch with all helpful agencies, philanthropic and otherwise.

It is a legal obligation upon parents to cause abnormal children to receive education, and it is the duty of the school authority to make provision for this special education. Parents are liable to contribute to these expenses. The Elementary Education (Defective and Epileptic Children) Act, 1899, requires that such children must be certified by medical practitioners approved by the Board of Education; and a defective child is defined as "not being imbecile and not being merely dull or backward, but capable of receiving benefit from instruction in a certified special class or school." In the Elementary Education (Blind and Deaf Children) Act of 1893, a blind child is defined as "one who is too blind to read ordinary school books," and a deaf child as "one who is too deaf to be taught in a class of hearing children." Both Acts make the period of compulsory education extend to 16 years of age.

Open-air recovery schools are of value more especially to children suffering from anæmia, incipient (closed) pulmonary tuberculosis, struma and scrofula, mental dulness and backwardness, and heart disease. Simple wooden or Doecker buildings suffice for open-air schools, and chairs or rugs are placed on the adjoining grounds both for class purposes and to enable children to rest and sleep for two hours after the early dinner. A nurse is in constant attendance; and great benefits, physical and mental, are derived by the children. Although the amount of formal teaching does not usually exceed three hours per day, the scholars are generally found to have kept their places on return to school; and improvements, in general appearance and carriage, in nutrition (as evidenced by weight), an increased amount of hæmoglobin in the blood, and an improved educational response, are generally to be noted. Something is also being done to supply the need for open-air residential schools, in addition to open-air day-schools.

The State has the right to intervene and protect a child not only against an employer, but also against its parents. That

this protection is needed in the educational interest of the child, apart from other considerations, was proved by an inquiry made some years ago, when it was estimated that 55,000 children under 14 years of age were working over 20 hours a week, in addition to the 27½ hours at school. Under such a strain it is certain that the physical health and development of young children must suffer, and the insufficient recreation involved in much out-of-school work must materially reduce the educational response. It is, therefore, important to briefly review the legal provisions which now exist for limiting the amount and regulating the nature of the out-of-school work which an elementary school child may perform. Under the Employment of Children Act, 1903, a child under 12 may not be employed; and a child of 12 or upwards may not be employed on Sundays for more than two hours, or on any school day before the close of school hours; nor on any day before 6 a.m. or after 8 p.m. It is, however, provided by the Education Act, 1918, that any local Education Authority may make a by-law somewhat modifying the above requirements in respect to certain occupations and children of 12 years and upwards.

The Prevention of Cruelty to Children Act, 1904, as amended by the Education Act, 1918, lays down the ages and hours of employment of children for the purpose of singing, playing, or performing for profit, or offering anything for sale. The employment of children up to 14 in factories, workshops, mines, and quarries is also prohibited by law; and the local Education Authority may further restrict employment of children when the school medical officer so advises.

3. The Spread of Infection in Schools.

Among the means of spreading infection by personal communication, compulsory school attendance at the most susceptible period of life must occupy a prominent place. At the present time we are dependent in our efforts to prevent the spread of infection in schools on (*a*) the compulsory information supplied under the Infectious Disease Notification Act, and (*b*) on the information supplied by teachers and others, as to mumps, whooping-cough, etc., in the districts where these diseases are not compulsorily notifiable. It is now usual for the medical officer of health, on the receipt of the notification of a case of

infectious disease in the person of a child attending school, to inform the school authorities of the case, so that all children in the same house attending school may be excluded until the premises are declared free from infection. If the child attacked is promptly removed to an isolation hospital, the room, clothes, and bedding can be at once disinfected, and the other children may be allowed to return to school on the expiration of the number of days corresponding to the maximum incubation period of the disease in question. If the child attacked is kept at home during its illness, the other children in the house must be excluded from school until the recovery of the patient and the disinfection of the premises. The diseases for which these precautions are especially necessary are small-pox, typhus, diphtheria, and scarlet fever; and measles and whooping-cough also, when such children are attending the infant departments of schools.

The medical officer of health has power, by issuing a certificate which is endorsed by the local sanitary authority or any two members of it, to close a school; or he may obtain such closure by getting the formal approval thereto of the school medical officer. Owing to the co-operation of the school officer and the officer of health it is now becoming unusual for the medical officer of health to take such action through the sanitary authority; but when this course is taken he must at once certify to the school medical officer, and this is also necessary when he excludes children from school attendance.

It is safe to conclude that, excluding the infant department, the large majority of children attending school have already suffered from measles; but in this, as in other infectious diseases, the proportions of those who have previously suffered will vary in different schools, and in different classes; and it is a great advantage in our efforts to control the spread of infectious disease to be able to refer to an infectious fever history of the scholars in each class. In the case of measles and whooping-cough, school closure rarely proves of value; good results have more often been obtained by closing a classroom on the ninth day after the occurrence of the first case, for five days; and then readmitting to the class only those who are quite free from any suspicious symptoms. A similar procedure may be adopted, in reference to mumps, chicken-pox, and whooping-cough. During the prevalence of measles all children with "colds"

should be excluded for three days, and the same rigid exclusion of all those who might conceivably be sickening has to be practised during the prevalence of other infectious diseases. In those cases where it seems desirable to go beyond the closure of a classroom or of a department and to close the school, neighbouring schools should be included in special circumstances, and the Sunday-schools should then also be closed. But only when there is imminent risk of an epidemic, or when the evidence points to a school or class as a source of infection, should class or school closure be resorted to. Certainly school closure in urban districts never offers the same advantages as school closure in rural districts, because in the former case the children mix so much out of school. The best preventive results are to be expected from a prompt exclusion of all suspects and carrier cases of infection; and as school teachers become better informed and more skilled in detecting suspicious cases of early infection, and as a frequent medical inspection of scholars during the epidemic prevalence of disease is more generally provided, the occasions on which school closure is demanded will become few and far between. In this connection it is only necessary to allude to the significance of brief absences of scholars, when infectious disease is prevalent in the district, and the dangers of then attempting to maintain high average attendances.

Whenever a sufferer, a contact, or a suspect, is excluded from school, it is important that a knowledge of this fact should be shared by the school medical officer, the medical officer of health, and the head-teacher of the school; and that preventive measures should include such internotification as will secure this end. Moreover, the school attendance officer should notify any such cases not already known to the school medical officer, the medical officer of health, and the head-teacher. It may also be necessary to obtain the closure of elementary schools for defective sanitary arrangements, which appear to have some connection with illness (such as enteric fever, diarrhœa, or diphtheria) occurring amongst the scholars.

To enable a decision to be arrived at as to what extra measures are called for, in order to reduce the spread of infection at schools, it is necessary to appreciate the fact that a larger part of the spread results from undiagnosed mild cases of infection than from children resuming school attendance too soon after the disease has been diagnosed and treated. The measure which

has met with most favour is to submit the scholars to repeated medical inspections during the exceptional prevalence of infectious disease, and to exclude all suspects from school attendance. A good knowledge of the early symptoms of communicable diseases enables teachers to take similar action day by day. It is most important that greater efforts should be made to promote this knowledge among school teachers. In all schools a medical man or woman should in non-epidemic times examine the scholars occasionally, with a view of detecting those numerous conditions which unfit a scholar temporarily for school attendance, or which require early correction, such as developmental defects, faulty vision, overpressure, and diseased conditions not necessarily infectious. He should also be able to make a prompt examination of every pupil referred to him at any time by a teacher, and should lecture to and instruct the teachers upon the symptoms of disease in school life. All suspicious cases should be excluded from school, and after diagnosis should be handed over to the care of their regular medical attendant, when such exists.

The common symptoms of fever are:—Irritability, peevishness, and drowsiness; nausea and vomiting; shivering fits; headache; loss of appetite, coated tongue, and thirst; frequent pulse and respirations; hot, dry skin or sweating; temperature above 100° F.

The chief special symptoms of the infectious fevers are:—

Diphtheria.—Extreme prostration; sore throat, with dirty white patches on tonsils; often noisy breathing and hoarseness, swelling of glands at angles of lower jaw, and nasal discharge ("Nasal Diphtheria"). No rash.

Scarlet Fever or Scarlatina.—Sore throat; vomiting; "strawberry tongue"; bright red rash, first on neck and upper chest, and then spreading over body; later a branny peeling of skin. May be discharge from ear.

Measles.—Symptoms of a bad "cold in the head"; then after three days a blotchy dusky-red rash appears on face and hands, soon spreading over body; often a hard cough; sometimes sore throat.

German Measles.—A rash, somewhat similar to Measles, but preceded by sore throat instead of cold in head.

Whooping-Cough.—A week or two of ordinary cough, and then a series of short violent expiratory coughs, followed by a long crowing inspiration ("whoop"), which may be followed by vomiting or nose-bleeding.

Mumps.—Painful swellings at sides of the neck, in front of and below ear; sometimes only on one side.

Enteric or Typhoid Fever.—Frontal headache; pains in limbs; nausea and vomiting; prostration; generally diarrhœa. A few small pink spots, chiefly on abdomen, after the tenth day of illness.

Small-Pox.—Sickness, backache, and considerable illness for a day or two; then pimples appear, first on face, which become watery blebs in 3 days and crusts in another few days.

Chicken-Pox.—Mild fever. Scattered pimples, first on body and fewest on face; rapidly becoming watery blisters. Crusts in 4 or 5 days.

N.B.—If child has been vaccinated Small-pox is generally very mild and resembles Chicken-pox.

Typhus.—Marked fever; great nervous disturbance (prostration, depression, etc.). Mulberry-hued spots and mottling of skin in parts—chiefly over stomach and on chest.

Influenza.—Shivering attacks; sneezing; running of eyes and nose; pains in limbs; great prostration; often cough.

Epidemic Cerebro-Spinal Fever.—Intense headache; persistent vomiting; stiffness and retraction of neck; pain down spine; drowsiness; varied rashes.

Tuberculosis of Lungs (Consumption).—Lassitude; loss of strength; wasting; cough and shortness of breath. The prevalence of this disease among school children varies somewhat in different districts. It probably does not exceed 1 per cent., on the average, in England and Wales; but the disease is more prevalent among the teachers.

The danger of infection is not necessarily proportional to the severity of the attack.

"A sudden cold in the nose or throat, a hot face, unnaturally bright eyes, a rash, a swollen neck, a cough ending in the characteristic whoop, a fit of sickness or shivering, a day or two of unusual irritability, are all signs which no one can afford to neglect."—*Board of Education*.

The circumstances favouring the spread of infectious diseases at school are:

Mild and unrecognized cases; "carrier" cases; and those incubating and in early stages of infectious diseases (especially Measles and Whooping-Cough). The close personal contact of scholars in classrooms and at play. The favourable ages of

the scholars. The too hasty return to school of sick children and "contacts." The favouring circumstances of cloakrooms, and of school books, etc., used in common.

The special precautions when an epidemic threatens or is established, are:—

Inspection of Scholars. Cleansing and Disinfection. The exclusion of children with possible Fever symptoms, such as—

If Diphtheria.—Those with sore throat, enlarged glands in neck, or nasal discharge.

If Scarlet Fever or German Measles.—Those with sore throat.

If Measles or Influenza.—Those with severe "cold," with sneezing, redness of eyes and running of nose.

If Whooping-Cough.—Those with a violent cough.

If Small-Pox.—Those with headache, vomiting, and pain in back.

If Enteric Fever.—Those with diarrhœa and abdominal discomfort or pain.

If Mumps.—Those with a swelling in front of or below ears.

The Education (Administrative Provisions) Act of 1907 requires the MEDICAL INSPECTION of all elementary school children at the period of commencing school attendance, and on such other occasions as the Board of Education may direct, and gives the local Education Authority power to make such arrangements in the health interests of the child as the Board of Education may sanction.

Since the passing of this Act the Board of Education has issued several circulars upon the subject of the medical inspection of children in public elementary schools. In the circular issued November, 1907, stress is laid upon the fact that school hygiene cannot be divorced from home hygiene, and that, generally speaking, the work of the inspection should be supervised by the medical officer of health of the authority which appoints the Education Committee. In appointing assistants for this work, it is suggested that preference should be given to medical men and women who have been trained in State medicine or hold the Diploma in Public Health, who have had some definite experience of school hygiene, and special opportunities for the study of diseases in children; the teacher, the school nurse, and the parents or guardians of the child must heartily co-operate with the school medical officer; the character and degree of medical inspection

is to embrace medical examination and supervision, not only of children known to be weakly or ailing, but of all children of the elementary schools, with a view to adapting and modifying the system of education to the needs and capacities of the child, procuring the early detection of unsuspected defects, checking incipient maladies at their onset, and furnishing the facts which will guide educational authorities in relation to the physical and mental development of the school child. The Board maintains that not less than three inspections during the school life of the child will be necessary to secure the results desired—namely, the first at the time of admission to school; the second at or about the third year of school attendance; and the third at or about the sixth year. A further inspection immediately before the departure of the child into working life is also advocated. It is required that the inspections should be made in school hours and on school premises; and that the facts revealed by inspection must be entered in a register kept at the school, a copy of the entries being transmitted to any other school to which the child may go. Every school medical officer must report annually to the local Education Authority, and send two copies of the report to the Board of Education; the report to deal with the calendar year. Local Education Authorities are to make arrangements without delay for obtaining amelioration of the evils revealed by medical inspection.

In a circular issued in August, 1908, the Board of Education draws attention to the fact that the school medical officer of the local Education Authority is for the first time recognized in the Education Code of 1908, as an officer having specific functions, as follows:

1. Those of reporting on the working and effect of any arrangements made under Article 44 for educating children at open-air schools or other places selected with the view to the improvement of the health and physical condition of the children.

2. The power of advising or approving the closure of the school on account of infectious disease.

3. The power of authorizing the exclusion of certain children from school on the grounds that such exclusion may prevent the spread of infectious disease.

The New Code also makes it a condition of grant that satisfactory provision for the medical inspection of children shall be made. In this circular it is further pointed out that where

medical inspection reveals defects, the first step should be to notify parents, and to urge the desirability of obtaining treatment by medical practitioners; that a school nurse is useful in assisting in the work of medical inspection, and in applying, or showing the parents how to apply, remedies for minor ailments; that after efforts to obtain the provision of spectacles by the child's parents or by any voluntary associations have failed, the Board will consider proposals for a local Education Authority to provide these free of charge; that before direct treatment of ailments is undertaken by the local Education Authority, whether by means of a school clinic or by themselves supplying and paying for medical treatment, full advantage should be taken of the benefits of such institutions as hospitals, dispensaries, etc., to the funds of which they are empowered to make a contribution. School clinics are either Inspection Clinics, where certain of the children found to be defective at the ordinary inspections are further examined, or Treatment Clinics, more especially for the treatment of eye, ear, and throat troubles, dental caries, and ringworm.

To whatever extent medical inspection may lead to the detection and alleviation of physical defects in school children, to a corresponding extent will children gain in general health and development; better results will be obtained from the teaching at school; the more healthy and physically fit child will be less a drag upon the resources of the family; and the State and posterity will benefit from a healthier stock.

Dr. Thresh compiled the following statistical table (1909), from the results of the medical inspection of over 40,000 children in certain counties and towns in England during 1908 and 1909:

Reported to be suffering from—	Approved Average Percentage.
Uncleanly head and body	18·0
Enlarged tonsils	13·0
Defective vision	13·0
Defective nutrition	8·0
Adenoids	8·0
Badly decayed teeth	8·0
Eye disease	3·0
Bodily deformity	2·4
Skin disease	1·9
External ear disease	1·8
Heart disease	1·5
Lung affections	1·4
Mentally defective	1·3
Tuberculous disease	0·8

SUMMARY OF REGULATIONS (LONDON COUNTY COUNCIL) WITH REGARD TO THE EXCLUSION OF CHILDREN FROM SCHOOL ON ACCOUNT OF INFECTIOUS DISEASES.

Disease.	Exclusion of Children suffering from the Disease.	Exclusion of Children living in Houses where the Disease exists.
Small-pox. Cholera.	(1) Until the medical attendant certifies, if the case is treated at home. (2) Until after discharge from hospital.	Until 7 days shall have elapsed after the date of the certificate from the Medical Officer of Health that the house is free from infection. In the event of the head-teacher not receiving the certificate that the premises are free from infection, it becomes his duty to send to the offices of the local Sanitary Authority, in order that he may procure it.
Diphtheria. Membranous Croup.	(1) If the case is treated at home, until a medical certificate, based upon bacteriological examination, is furnished. (2) Until a fortnight after date of discharge from hospital.	
Scarlet Fever or Scarlatina.	(1) Until the medical attendant certifies, if the case is treated at home. (2) Until a fortnight after date of discharge from hospital.	
Erysipelas. Typhoid Fever or Enteric Fever.	(1) Until the medical attendant certifies, if the case is treated at home. (2) Until after discharge from hospital.	Not to be excluded. No proceedings to be taken to enforce attendance if Medical Officer of Health specifically orders exclusion.
Measles.	At least one month.	*Infants*.—All infants to be excluded until Monday following 14 days from occurrence of *last* case. *Seniors*.—If child has had the disease, NOT to be excluded. If child has not had the disease, exclude until Monday following 14 days from occurrence of *first* case.
Mumps.	One month.	*Infants*.—All infants to be excluded for such time as medical attendant considers necessary. If no medical attendant, for three weeks. *Seniors*.—If child has had the disease, NOT to be excluded. If child has not had the disease, exclude for the same period as infants.

Summary of Regulations (London County Council) with Regard to the Exclusion of Children from School on Account of Infectious Diseases—*Continued.*

Disease.	Exclusion of Children suffering from the Disease.	Exclusion of Children living in Houses where the Disease exists.
Whooping-cough.	As long as the cough continues, but not to be readmitted until at least 5 weeks from the commencement of whooping.	*Infants.*—All infants to be excluded two weeks. *Seniors.*—If child has had the disease, NOT to be excluded. If child has not had the disease, exclude for two weeks.
Chicken-pox.	Two weeks, or until every scab is off scalp or body.	*Infants.*—All infants to be excluded for two weeks. *Seniors.*—If child has had the disease, NOT to be excluded. If child has not had the disease, ex clude two weeks.
Ringworm, Favus. Ophthalmia (Blight). Trachoma. Scabies (Itch).	Until medical certificate is obtained that the child is cured. Wherever certificates are not readily procurable, teachers to exercise their discretion as to readmission, and, if in doubt, to ask school nurse.	Not to be excluded.
Consumption.	Exclude if the disease is accompanied by coughing or spitting.	Ditto.

Note.—If a medical attendant or the Medical Officer of Health should certify, in any special case, that the above periods of exclusion should be extended, teachers are to observe such instructions, and to at once communicate with the Medical Officer (Education).

SCHEDULE OF MEDICAL INSPECTION ISSUED BY THE BOARD OF EDUCATION.

Schedule of Medical Inspection.

I.—Name________________ Date of birth[1]____________

Address________________ School ________________

II.—Personal History:

(*a*) Previous illnesses of child (before admission).

Measles.	Whooping-cough.	Chicken-pox.	Scarlet. Fever.	Diphtheria.	Other Illnesses.[2]

(*b*) Family medical history (if exceptional).[3]

	I.	II.	III.	IV.
1. Date of inspection				
2. Standard and regularity of attendance[4]				
3. Age of child[5]				
4. Clothing and footgear[6]				
III.—*General Conditions.*				
5. Height[7]				
6. Weight[8]				
7. Nutrition[9]				
8. Cleanliness and condition of skin[10]				
Head				
Body				
IV.—*Special Conditions.*				
9. Teeth[11]				
10. Nose and throat[12]				
Tonsils				
Adenoids				
Submaxillary and cervical glands				
11. External eye disease[13]				
12. Vision[14]				
R.				
L.				
13. Ear disease[15]				
14. Hearing[16]				
15. Speech[17]				
16. Mental condition[18]				
V.—*Disease or Deformity.*[19]				
17. Heart and circulation[20]				
18. Lungs[21]				
19. Nervous system[22]				
20. Tuberculosis[23]				
21. Rickets[24]				
22. Deformities, spinal disease, etc.[25]				
23. Infectious or contagious disease[26]				
24. Other disease or defect[27]				
Medical officer's initials				

General Observations.
Directions to Parent or Teacher.

Reference Number of Note.

NOTES FOR INSPECTING OFFICER.

[1] Date of birth to be stated exactly, date of month and year.

[2] "Other illnesses" should include any other serious disorder which must be taken into account as affecting, directly or indirectly, the health of the child in after-life—*e.g.*, rheumatism, tuberculosis, congenital syphilis, small-pox, enteric fever, meningitis, mumps, fits, etc. The effects of these, if still traceable, should be recorded.

[3] State if any case of, or deaths from, phthisis, etc., in family.

[4] Note backwardness.

[5] Age to be stated in years and months, thus $5\frac{4}{12}$.

[6] Insufficiency, need of repair, and uncleanliness should be recorded (good, average, bad).

[7] Without boots, standing erect with feet together, and the weight thrown on heels, and not on toes, or outside of feet.

[8] Without boots, otherwise ordinary indoor clothes.

Height and weight may be recorded in English measures, if preferred. In annual report, however, the final averages should be recorded in both English and metric measures.

[9] General nutrition as distinct from muscular development or physique as such. State whether good, normal, below normal, or bad. Under-nourishment is the point to determine. Appearance of skin and hair, expression, and redness or pallor of mucous membrane, are among the indications.

[10] Cleanliness may be stated generally as clean, somewhat dirty, dirty. It must be judged for head and body separately. The skin of the body should be examined for cleanliness, vermin, etc.; and the hair for scurf, nits, vermin, or sores. At the same time ringworm and other skin diseases should be looked for.

[11] General condition and cleanliness of temporary and permanent teeth and amount of decay. Exceptional features, such as Hutchinsonian teeth, should be noted. Oral sepsis.

[12] The presence or absence of obstruction in the naso-pharynx is the chief point to note. Observation should include mouth-breathing; inflammation, enlargement, or suppuration of tonsils; probable or obvious presence of adenoids, polypi; specific or other nasal discharge, catarrh, malformation (palate), etc.

[13] Including blepharitis, conjunctivitis, diseases of cornea and lens, muscular defects (squints, nystagmus, twitchings), etc.

[14] To be tested by Snellen's test types at 20 feet distance ($=6$ metres). Result to be recorded in the usual way—*e.g.*, normal $V.=\frac{6}{6}$. Examination of each eye (R. and L.) should as a rule be undertaken separately. If the V. be worse than $\frac{6}{9}$, or if there be signs of eyestrain or headache, fuller examination should be made subsequently. *Omit vision testing of children under six years of age.*

[15] Including suppuration, obstruction, etc.

[16] If hearing be abnormal, or such as interferes with class-work, subsequent examination of each ear should be undertaken separately. *Apply tests only in a general way in case of children under six years of age.*

[17] Including defects of articulation, lisping, stammering, etc.

[18] Including attention, response, signs of overstrain, etc.

The general intelligence may be recorded under the following heads: (*a*) Bright, fair, dull, backward; (*b*) mentally defective; (*c*) imbecile. *Omit testing mental capacity of children under six years of age.*

[19] Under the following headings should be inserted particulars of diseased conditions actually present or signs of incipient disease. The extent of this part of the inspection will largely depend upon the findings under previous headings.

[20] Include heart-sounds, position of apex-beat, anæmia, etc., in case of anything abnormal or requiring modification of school conditions or exercises.

[21] Including physical and clinical signs and symptoms.

[22] Including chorea, epilepsy, paralysis, and nervous strains and disorders.

[23] Glandular, osseous, pulmonary, or other forms.

[24] State particular form, especially in younger children.

[25] Including defects and deformities of head, trunk, limbs. Spinal curvature, bone disease, deformed chest, shortened limbs, etc.

[26] Including any present infectious, parasitical, or contagious disease, or any sequelæ existing. At each inspection the occurrence of any such diseases since last inspection should be noted.

[27] Any weakness, defect, or disease not included above—*e.g.*, ruptures—specially unfitting the child for ordinary school life or physical drill, or requiring either exemption from special branches of instruction or particular supervision.

CHAPTER XII

INDUSTRIAL HYGIENE—MARINE HYGIENE

INDUSTRIAL HYGIENE.

GREAT BRITAIN was the pioneer of legislation to protect the industrial worker. From the first decade of the last century, onwards to the Employment of Women, Young Persons, and Children Act of 1920, Parliament has restricted the employment of children in mines, and of women and children in factories; improved the conditions of work within factories and workshops; provided for the medical inspection of certain workers by certifying factory surgeons; and required the adoption of measures for preventing the diseases which have been recognized as associated with particular occupations. In no field of human activity has the adoption of preventive measures against disease furnished more prompt and satisfactory results. The following facts will suffice to indicate the progress that has been made:—Industrial dust diseases (including anthrax) have been considerably reduced, and ganister disease is now rare among such workers. Industrial poisonings no longer claim the numerous victims of former years; lead poisoning in the potteries of Great Britain has been reduced to about one-eighth of its former prevalence within the twenty years ending 1920; in the white lead industries the reduction has exceeded 90 per cent., and in paint and colour works the reduction has reached some 75 per cent. during the same period; only one case of phosphorus necrosis has been reported in recent years. Moreover, the general sick-rate of the industrially employed has been improved. The miner (in coal, ironstone, and metalliferous mines) has had the danger of his occupation from accidents reduced to less than one-third of that of some seventy years ago; and the Mining Industry Act, 1920, (which, *inter alia*, provides for a "welfare fund"), and recent Orders under the Coal Mines Act, 1911, are destined to effect still further reductions. Such accidents have been reduced as the result of

the careful inspection of the air in particular workings before the miner descends, the better signalling, the improved ventilation by the double shaft method, and the better supervision of the haulage. The number of deaths from explosions of fire damp and coal dust is now quite small.

The following table sets out the comparative mortality figures of the most important causes of death among those engaged in certain occupations:

Class.	Phthisis.	Diseases of the Nervous System.	Diseases of the Circulatory System.	Diseases of the Respiratory System.	All Causes.
All males	186	105	144	174	1,000
Labourer in agricultural districts	75	52	102	80	567
Coal miner (Lancashire)	98	77	121	**261**	939
Wool, Worsted operative	161	92	**150**	155	917
Hosiery operative ..	**200**	93	129	142	862
Cotton operative ..	**214**	100	140	**199**	**1,010**
Innkeeper, publican	**232**	**175**	**209**	**250**	**1,709**
Tailor	**243**	89	123	145	950
Shoemaker	**247**	83	136	140	916
Potter	**291**	98	**199**	**425**	**1,372**
Printer	**323**	71	107	110	903
Cutler	**506**	105	**206**	**300**	**1,468**
Tin miner	**851**	77	**161**	**735**	**2,160**

Figures above the standard set by all males are printed in heavy type.

Thus a new science of labour is being developed, and this, based on combined research and experiment by scientific workers as well as on business methods, and receiving the sympathetic co-operation of employers and workers, is pregnant with great issues of health and happiness to the human race.

The place given in the Peace Treaty to constructive work by the League of Nations for the social welfare of labour constitutes another great forward step.

The Factory and Workshops Acts secured a great measure of control in respect to the age and sex conditions of labour and the limitations to overtime work, the sanitation of factories and worshops, the health of the workers (medical inspection), and the precautions demanded in the dangerous industries.

In recent years, as the more scientific organization of industrial energy is developing, the scope of industrial hygiene has widened. It is now recognized that for the most economical conduct of an industry the human element must operate under optimum conditions, and that there must be a socialized aim in production. Especially have the vast national loss and evil effects of unduly prolonged work, and their aggravation by improper conditions of work, been demonstrated. The regard for the hygiene, comfort, and general well-being of the workers in munition and other war material producing work during the Great War, the findings of the Committee upon the Health of Munition Workers, and the issue of Welfare Orders by the Home Office in respect to certain industries, have all conduced to this. The recent step of bringing industrial disease arising out of employment, like accidents, within the operation of the Workmen's Compensation Act, must also prove a real help in promoting industrial hygiene.

An Industrial Fatigue Research Board, appointed in 1918, is dealing with the following terms of reference:—

"To consider and investigate the relations of the hours of labour and of other conditions of employment, including methods of work, to the production of fatigue, having regard both to industrial efficiency and to the preservation of health among the workers."

The appointment of welfare-workers and the establishment of works committees on which both the management and the workers are represented, are serving in no small measure to secure a higher standard of healthy working efficiency; to these ends the pioneer work due to voluntary efforts by a number of employers has been most helpful. The introduction of female factory inspectors and of the forty-eight hour week, are also noteworthy recent developments.

It is now recognized that:—

1. Work under optimum conditions of duration, healthy surroundings, good feeding and housing, not only promotes health and efficiency and greatly reduces industrial sickness, but also leads to an increase in the quality and quantity of production and diminishes its costs, while increasing well-being and content among the workers. Sunday labour is not economical, and should be reduced to a minimum.

2. The provision for medical inspection (especially of young people on entering a factory) and medical supervision is most

important. Such "works-doctors" are at present more in evidence in Belgium and the U.S.A. than in this country.

3. Ambulance or first-aid provisions have proved their value by preventing sepsis, and thus reducing the time lost from accidents; massage centres serve more quickly to restore workers to the ranks of the physically fit; and provisions for dental work, vision-testing, and spectacles prove truly economical.

4. Greater efforts are called for to maintain health by preventing many forms of disabling sickness. Actual disease is an end-process, and the processes which lead up to it need more study. Certain forms of industrial poisonings and anthrax have been attacked with great success; industrial hygiene still awaits an equal success in respect to more common diseases which unduly attack the industrial worker, such as bronchitis, phthisis, heart disease, and rheumatism.

Records of accidents and sickness, in addition to those of mortality, are needed to be kept and studied with a view to the adoption of preventive measures, for they represent a heavy national loss which can be substantially reduced. It may be stated that from six to seven days are lost, on the average, by each person industrially employed during each year, and it is estimated that at least 25 per cent. of this loss from sickness is preventable. Tuberculosis is the chief disease cause of industrial loss, and it is computed that about 3 per cent. of the whole industrial population contract this disease.

5. There remains much evidence of the need for greater cleanliness and better ventilation, lighting, and warming in factories and workshops. Good lighting is necessary from the standpoints of eyesight, health, safety, efficiency, and discipline. A Departmental Committee appointed in 1913 recommended that there should be a statutory provision requiring adequate and suitable lighting, and giving power to the Secretary of State to make Orders defining adequate and suitable illumination for factories and workshops, or for any parts thereof, or for any processes carried on therein. Over-heated and over-moist atmospheres, as in some processes in cotton mills, greatly conduce to inefficiency; and there appears to be a definite relationship between working efficiency and the dry cooling power of the air.

6. Accidents are prevented more by the education of the workers to personal care than by guards or fencing to machinery; and "Safety Companies," composed of workers, are to be recommended.

7. Wholesome drinking water, required under an Order (1917), is an essential provision.

8. *Welfare work* in factories and workshops is to the mutual advantage of employer and employee; and where it has been adopted the workers are more efficient, happy, and contented. Welfare work relates to the hygiene, safety, feeding, recreation, and housing of the workers. The leisure of the worker, according to the use made of it, may make or mar his workmanship. A worker's canteen, club, recreation ground, and hostel, are among the provisions generally made. A Welfare Supervisor (female for women and girls, and male for men and boys) should be well trained, a capable social worker, and a convinced and practical sanitarian, always with an eye upon the physical and mental well-being of the workers. He or she should be part of the management of the factory, practically familiar with the industry, sympathetic of the interests of the employer and of the employees, and well received by the management, workers, and foremen and forewomen, and acquainted with the feelings of the workers; should receive, consider, and report to the firm any suggestions made by the workers; should be well informed on dietary and acquainted with canteen management. He or she should organize clubs (including thrift societies), rest-rooms, amusements, etc.; by home visiting and advice and stimulation should seek to improve the home conditions of the workers; if boys are engaged, should see that their educational needs do not suffer; and if female labour is employed, should try and secure lighter work and milk drinks before and after pregnancy, and facilities for the breast-feeding of the infants. Furthermore, opportunities should be taken for correcting such practices or habits among individual workers as tell against their health and efficiency, and for the dissemination of general health information.

A considerable number of Welfare Supervisors have been appointed; and many firms carry out welfare work by means of *ad hoc* committees, or (in smaller works) one of the directors undertakes these duties.

9. There is probably more poor health among the women

industrially employed than among the men. This may be due to their poorer feeding and inferior physical powers, and they have, moreover, to bear the strain of home duties, of maternity, and claims of offspring. Decayed teeth and anæmia are more prevalent among them. Such employment opposes itself to the proper discharge of home duties, the demands of ante-natal and post-natal hygiene, and the claims of offspring. In France it has been demonstrated that when pregnant women retire from work for 4 or 6 weeks before confinement, the infant is stronger and heavier at birth. Cessation of work for 8 weeks—3 or 4 before and 4 or 5 after the confinement—is generally accepted as a reasonable arrangement. Where a large amount of female labour is employed a small works crêche, with facilities for the mothers to suckle their infants, ought to be provided. It is in light mechanical operations that woman's work is at its best; and a weight of 40 to 50 pounds represents the maximum that women of average physique should be asked to lift. Married women ought never to be engaged in night work.

10. The vocational selection of workers for work to which they are fitted is of great importance; as is also instruction upon how best to apply their energy. Neglect of these matters entails a heavy economic loss from restricted output.

11. The harmful conditions of industrial work generally depend more on unsatisfactory environmental conditions than on the tax imposed on physical energy.

12. A break in the daily routine of labour in the form of a fortnight's holiday annually is desirable, rather as a relief from the monotony of the work than from health considerations.

13. It may be claimed that the Daylight Saving Act has been helpful to the well-being of the industrial worker in factories and workshops.

14. The prohibition of alcohol in America appears to be associated with improved industrial efficiency, whether measured by accident frequency, lost time, or output.

15. A greater attention to feeding provisions should help to overcome the fatigue and lassitude which often lead to drinking.

Industrial Fatigue.

There is a limit beyond which the human machine can no longer produce satisfactorily; if this is exceeded, there is an impairment of quality and reduction in quantity of the work; damage to health results, and accidents may occur. The shortening of unduly long hours of labour under improved hygienic conditions is followed by an increased productive efficiency. Night work is often deleterious to health, and is generally inferior to day work in its results.

Obviously the number of hours of work cannot be the same for all individuals and for all industries. Research is needed before the desideratum of a good time-table of work and rest for each kind of labour and for each sex, and under all climatic conditions, can be furnished.

It is generally agreed that fatigue results from the action upon the tissues of the carbonic acid and lactic acid formed by the chemical dissolution of the glycogen of overworked muscles. These products, locally produced, not only cause fatigue in the local neuro-muscular apparatus, but since they find their way into the blood stream, they may affect the higher nerve centres in the brain. The presence of a leucocytosis in the blood, consequent upon exhausting work, has been demonstrated. The signs and onset of fatigue depend on the nature and conditions of the work, and such signs may not be obvious to the worker. Hard work which demands close attention, and is performed in overheated noisy factories, may affect the nervous system more than the muscular. The evil effects of fatigue may be cumulative, if they are not entirely got rid of daily, or at most weekly.

The most direct test of fatigue is the measurement of outpu over many days, and this must be made without the knowledge of the workers. The use of ergometers and dynamometers, etc., is less satisfactory.

Good individual outputs of work may indicate good methods, and point to the desirability of allotting certain workers to particular tasks.

Spells of work which are too long should be broken by organized rest pauses. Unfavourable influences due to temperature, humidity, and lighting have a considerable effect, and these are controllable by well-planned ventilation and illumination. In

occupations demanding continuous application and attention, the working periods should not exceed three hours; and in arduous work frequent rest spells should be provided.

Welfare Orders.

The Secretary of State has made various Welfare Orders (1917–21), which relate to certain industries, under the Police, Factories, etc. (Miscellaneous Provisions) Act, 1916. These provide for:—

1. Suitable protective clothing and boots in certain processes involving exposure to wet and soiling.

2. Suitable overalls and armlets for persons engaged in sorting soiled linen in laundries.

3. Suitable accommodation for clothing removed during working hours, and adequate arrangements for drying wet clothing.

4. A suitably equipped and warmed mess-room, kept separate from any cloak-room.

5. Suitable facilities for washing adjacent to where the work is done.

6. Where oil cake is manufactured, if half of the employees so apply, shower baths (one for every fifty persons) must be provided, with a sufficient supply of clean towels and soap.

7. In all factories and workshops in which twenty-five or more persons are employed, an adequate supply of wholesome drinking water, with an upward jet or drinking vessel at each point of supply. The water to be guarded from contamination.

8. Facilities for female workers to be seated either during work or when opportunities for resting occur.

9. A sufficient number of suitably stocked "first-aid" boxes to be provided in readily accessible positions (at least one to every 150 persons).

10. Where the number of persons employed is 500 or more, an ambulance room and ambulance in charge of a nurse or person qualified for first-aid may be required where accident risks are high. Floor space of room to be at least 100 square feet.

11. All accommodation provided must be placed under the charge of a responsible person and kept clean, and the cost of all provisions falls upon the employers.

Industrial Diseases.

Irritating Dusts.

Comparative Mortality of Males, Twenty-five to Sixty-five Years of Age, in Certain Dust-inhaling Occupations from Phthisis and Diseases of the Respiratory Organs.[1]

	Phthisis.	Diseases of the Respiratory Organs.	Phthisis and Diseases of the Respiratory Organs.
Coal miner	126	202	328
Carpenter, joiner	204	133	337
Baker, confectioner	212	186	398
Plumber, painter, glazier ..	246	185	431
Mason, builder, bricklayer ..	252	201	453
Wool manufacturer	257	205	462
Cotton manufacturer	272	271	543
Quarryman (stone, slate) ..	308	274	582
Cutler	371	389	760
File maker	433	350	783
Earthenware manufacturer ..	473	645	1,118
Cornish miner	690	458	1,148
All males (England and Wales)	220	182	402
Fishermen	108	90	198

It is important to note that the column under phthisis in the above table represents the tubercular form of this disease, but undoubtedly includes many cases of fibroid phthisis as well.

More recently Dr. Tatham furnished a valuable contribution[2] on the varying rates of mortality among men engaged in different occupations, the main conclusions being based upon the deaths that occurred during the three years 1890-92 among males between twenty-five and sixty-five years of age—the period during which the effect of occupation is assumed to be most marked, and in which the proportion of occupied males is largest. Taking 1,000 to represent the mortality of all males at these ages in England and Wales, the comparative mortality figure for all *occupied* males was 953, and while it was 687 in agricultural districts, it reached to 1,248 in industrial districts. The com-

[1] Dr. Ogle's Report, Supplement to the 45th Annual Report of the Registrar-General.

[2] Supplement to the 55th Annual Report of the Registrar-General.

parative mortality figures of males from twenty-five to sixty-five years of age was low for clergymen (533), gardeners (553), farmers (563), school teachers (604), farm labourers (632), and lawyers (821); for medical men it was 966; and it was high among brewers (1,427), general labourers in industrial districts (1,509), publicans (1,642), costermongers (1,652), and hotel servants (1,725). The excessive mortality of cutlers, file makers, scissors makers, and nail makers, noted in previous periods of observation, was still high in 1890-92; and slaters, tilers, wool, silk and cotton dyers, potters, glass manufacturers, tin miners, coal heavers, and chimney sweepers again showed marked excess of mortality.

In Dr. Tatham's report the figures bearing upon the fatal effects of breathing dust-laden air, or air fouled in other ways, have acquired increased value from the careful elimination of the disturbing influences of the varying age proportions of persons engaged in different occupations. Taking 100 to represent the combined mortality from phthisis and diseases of the respiratory organs among those engaged in agricultural occupations, the comparative figures from these diseases among those engaged in occupations which cause dust of various kinds reaches 373 for file makers, 407 for cutlers and scissors makers, and 453 for potters and earthenware manufacturers.

That *coal miners* should stand at the head of Ogle's list, as regards freedom from lung diseases, is somewhat surprising, considering that the air in the underground passages in which they work, even in the best-ventilated mines, is vitiated by respiration, combustion of lights, and blasting agents, which throw into the air much CO_2, CO, H_2S, etc. In addition, CO_2 and CH_4 are often evolved in considerable volumes from the strata cut through by the shafts and borings, and the air in the workings is often thick with coal dust. Dr. Ogle explains the comparative innocuity of coal dust in causing lung disease by the microscopical character of its particles, which are comparatively free from sharp points and corners. He is also inclined to attribute to coal dust a special property of hindering the development and arresting the progress of tuberculosis—a disease, it is to be remembered, which might be expected to be very fatal to coal miners, from the fact of their working in a heated vitiated atmosphere, and being liable to sudden alterations of temperature in going to and leaving off work. Where there is a considerable proportion of stony

particles in the coal, lung diseases appear to be favoured; and this no doubt accounts for the fact that the incidence of miners' phthisis in different collieries is unequal.

Experiments upon the lower animals indicate that carboniferous particles arrested in the nasal and pharyngeal passages, and afterwards swallowed, may pass through the intestinal epithelium and through the lymphatic system, finding their way into the thoracic duct and thence into the venous circulation, to be ultimately arrested in the capillaries of the lung. These experiments also demonstrated that in young animals the carbon particles do not readily get beyond the mesenteric glands. In animals and men the lungs soon rid themselves of such particles when the broncho-tracheal glands are healthy; but when these latter have become injured, as in the case of miners, definite anthracosis supervenes.

Statutory rules and orders which have been issued under the Coal Mines Act, 1911, deal, amongst other matters, with precautions against coal dust and against the spontaneous combustion of coal, and with rescue work in coal mines. In all mines in which coal other than anthracite is worked—those mines being excepted in which the floor, roof, and sides of the roads are naturally wet throughout—it is laid down that the walls of the roads shall be treated (1) with incombustible dust in such manner and at such intervals that the resultant dust mixture shall contain not more than 50 per cent. of combustible matter; or (2) with water, so as to ensure that the dust is combined with 30 per cent. of water in intimate mixture; or (3) in such other manner as the Secretary of State may approve. No injurious dust is to be introduced; the use of gritty dusts or those containing a large proportion of free crystalline silica, both of which are injurious to health, appears to be precluded by the regulation which specifies that at least 50 per cent. of the added dust must be capable of passing through a sieve with 200 meshes to the lineal inch. Subject to a provision that the Divisional Inspector of Mines may allow an extension where the necessary provision of plant has been difficult, the foregoing regulations came into force on January 1, 1921. In mines in which safety lamps are required, and in such other mines as the Secretary of State may direct, on the appearance of smoke or other sign indicating that a fire may have broken out below ground, workmen must be withdrawn from the districts affected; before re-admission certain officials must examine and report. If a fire has been ascertained,

precautions are laid down. For rescue work, the breathing apparatus must be of approved type and tested monthly; where there is a uniform oxygen delivery, the supply must not be less than 2 litres of oxygen (with not more than 2 per cent. of impurities) per minute. Members of rescue corps must pass certain medical and physical tests and practices with breathing apparatus. A qualified medical man must be in attendance when rescue parties are at work (unless held to be unnecessary by manager, Inspector of Mines, and miners' representative), and any man engaged in rescue work must be examined before going underground a second time.

At every mine to which the regulations apply a room must be provided and maintained exclusively for rescue and aid purposes; this room, distinguished by a large red cross on the door, must have a floor space of not less than 100 square feet, and must be supplied with adequate natural and artificial lighting, with satisfactory heating, and with a plentiful water supply; it is to be placed in charge of a person holding a certificate of proficiency in first-aid from an approved society.

The comparative immunity of coal miners from tubercle is not displayed by the *Cornish or tin miners*, who come at the bottom of the list. Their mortality from lung diseases constitutes nearly two-thirds of their total mortality, and is nearly three times as great as that of Cornish males generally. They work under conditions of heated and vitiated air like the coal miners, but they inhale a sharp, angular, and most irritant stone dust, instead of the comparatively smooth coal dust. All metalliferous miners working in hard stone are exposed to dust inhalation; but those who are most exposed are those who employ drilling or boring machines acting by percussion (compressed air). A jet or spray of water directed upon the rock, when the drill is at work, is a valuable means, which has been largely adopted, of keeping down this dust. Gold miners also are short-lived, and suffer largely from phthisis. The other occupations in which the workers are exposed to the inhalations of stone dust are *masons, builders*, and *bricklayers*, who carry on their work chiefly in the open air, and have a lung disease figure of 453; *stone* and *slate quarrymen*, who also mainly work in the open air (582); and the *earthenware, china*, and *pottery manufacturers*, who suffer enormously from pneumonia, bronchitis, and emphysema (potters' asthma), and phthisis. Among these latter the lung disease mortality is

nearly the same as that of the tin miners. They carry on their trade in close and heated factories, and, besides the fine irritating dust, are exposed to great vicissitudes of temperature. The chinaware is baked with flint dust, and this is subsequently brushed off by women, the process being known as "china scouring." This process is especially dangerous, the silicious constituents of the dust being the chief cause of mischief.

Cutlers and *file makers, needle, pin,* and *tool makers,* are exposed to metallic dust and stone dust given off from the grindstones, and they suffer from phthisis, bronchitis, and pneumonia. The old-time sandstone wheels employed in the grinding of metals, and which distributed silica dust, are steadly being replaced by wheels made of a composition which gives rise to dust which is less in amount and more easily collected by exhaust ventilation. File makers are in addition liable to lead poisoning, from their using a cushion of lead on which to strike their file. In these trade processes the dust should be collected, as far as possible, by hoods placed immediately over the benches which lead into a common outlet shaft, the draught in which is maintained by a revolving fan. Or, where hoods are inconvenient, perforated metal plates may be let into the benches and hopper expansions of the outlet shafts fitted immediately below these plates; the fan then pulls air, and with it the dust, through the perforations of the metal plates. The dust from the common outlet shaft may be allowed to settle in a dust chamber, or be arrested by filtering the air through canvas screens, or by a water surface or spray. The workers should be made to wear respirators in the more dusty rooms; and in steel grinding, magnetic shields are useful for attracting and collecting the steel dust. In the grinding trades the grindstone may be enclosed in a hood or casing connected to a powerful exhaust fan. This is especially desirable in dry grinding; and, where necessary, glass may be let into the hood to permit light to pass to the grinding surface. Dr. Harold Scurfield has shown (1908) that the death-rate of grinders from phthisis is more than six times that from respiratory diseases, and nearly three times that of the average male in Sheffield; also that in the case of cutlers the death-rate from phthisis is nearly three times that from respiratory diseases, and four times that of the average male in Sheffield. The first direct result of this form of dust inhalation is an irritation of the mucous membrane of the nasal passages, often with erosion and

ulceration, followed by atrophy and loss of smell. This atrophy facilitates the entrance of dust into the lungs, and fibrotic inflammatory masses form, which ultimately break down, leaving cavities which frequently become inoculated with the tubercle bacilli. Hence those who contract this pneumoconiosis are very liable to die from a superimposed tubercle infection.

The operatives in *cotton factories* work in a heated atmosphere saturated with moisture by steam, and laden with filamentous particles of cotton and mineral substances used for sizing. A standard of purity of the air is now enforced, by which the CO_2 may not exceed 0·09 per cent. in the artificially moistened sheds. In order to avoid the consequences of heavy steaming, Haldane has suggested that a fine spray of cold water should be employed instead of hot steam. During the Great War it was found that only 19·6 per cent. of the males working as cotton weavers could be classified as Grade A for the purposes of conscription. In *woollen factories* the heat is not so great, and there is less dust owing to the wool being treated with oil; but wool sorters are liable to contract anthrax from infected fleeces. In *silk mills*, dust and high temperature are injurious to the material, and are consequently avoided.

Millers and *bakers* are liable to inhale flour dust, but as this substance is probably arrested in the mouth and nose, and does not reach the lungs, it can hardly be regarded as productive of lung disease. *Carpenters*, *joiners*, and *cabinet makers* are exposed to wood dust. The dust from the harder kinds of wood is probably more injurious than that from the softer kinds.

There was formerly a great mortality among those engaged in the "ganister" industry. Ganister is a very hard silicious stone, with a very high fire-resisting capacity, and it is used for lining the bottoms of crucibles, etc. Formerly, a very large proportion of the workers died from fibroid phthisis.

Millstone masons also suffer largely, the phthisis death-rate of these workers being nearly ten times as great as that among the general male population of corresponding ages.

The well-defined causes of danger, such as dust, fumes, gas, fire, explosion, etc., affecting some other industries are found in complicated combination in the chemical industry, in which the materials dealt with are, generally speaking, more dangerous than in other industries.

Industrial Poisonings.

The degree of susceptibility to industrial poisons varies in different industries, and a degree of tolerance is often established among workers.

Lead poisoning may result from direct absorption of the metal through the skin, but more commonly by swallowing, or by inhalation of the vapours or powder of lead compounds. The trades most liable to suffer are: Workers with white lead; electric accumulators, painters and plumbers, tinning, painting and colouring, enamelling, smelting metals, china and earthenware, coach painting, file cutting. Lead miners do not suffer in this country from lead poisoning.

Carbonate of lead, or white lead, is very extensively used as a paint, and many coloured paints contain the metal. Both the acetate and the nitrate of lead are used in calico printing and cotton dyeing to produce orange and yellow colours. Sulphide of lead is used mainly for glazing pottery, bricks, etc., and oxide of lead is used in enamels.

File makers are liable to lead poisoning from their using a cushion of lead on which to rest the file while the rough surface is being prepared by means of a blunt chisel struck with a hammer. The glass grinders may be poisoned from the constant contact with the putty powders (rich in lead) which are used for polishing the glass; and the type founders and type setters from the constant handling of the type metal—an alloy of lead, tin, and antimony.

At present the most common causes of lead poisoning are the working with lead glazes, and the manufacture of white lead and electric accumulators. "The proportion of severe cases among file cutters and those engaged in coach painting, in ship building, and in other industries where paint is used, exceeds that of those engaged in industries where the danger is primarily from the dust of salts of lead" (T. M. Legge, H.M. Medical Inspector of Factories). Plumbers inhale volatilized oxide of lead and painters the dust of white lead, but lead is also taken into the system when meals are taken with dirty hands.

The most characteristic symptoms are colic, wrist-drop, anæmia, and the lead line in the gums.

Female labour in the dangerous processes was abolished in 1893, as miscarriages, still-births, and the premature death of infants from convulsions, etc., result from lead poisoning in the mother.

Sanitary Precautions.—1. All fumes and dust should be collected as rapidly and completely as possible as they are formed and conducted, by means of a powerful exhaust, to condensing chambers or washers; so that the air of the workplaces may be kept as pure as possible, and the external atmosphere around the works also saved from pollution.

2. The handling of the metal, or of substances containing lead, should be reduced to a minimum.

3. Every facility and encouragement should be given to the workers to practise personal cleanliness. Mouth washes and tooth and nail brushes should be used before partaking of a meal. Strict

rules should be enforced for the washing of hands. A basin, tap, and towels must be supplied for at most every five persons.

4. In the more dusty rooms overalls, close fitting round the neck and wrists, and respirators are desirable, in addition to exhaust fans to remove dust and insure abundance of fresh air.

5. Meals should not be permitted to be taken in any of the workrooms. Sanagen forms a very insoluble albuminate with lead and most of the other metallic poisons, and is valuable also in the treatment of these conditions.

6. There must be periodical medical inspection of the workers. Those who are more especially susceptible to the poisonous effects of the metal should at least be excluded from the more dangerous rooms. This will apply to all women and children. All those with cuts or sores should be excluded from the works.

7. Sulphuric acid lemonade is recommended as a drink for the workpeople, as it favours the formation of the less soluble sulphate of lead; the free drinking of milk is also recommended, so as to form the little soluble albuminate of lead.

8. The workrooms must be kept clean, well ventilated, and as free from dust as possible. The immediate removal of the dust is the essential preventive measure in china and earthenware factories, in places where processes connected with white and red lead are carried on, in paint and colour factories, in all workrooms in which operations of litho-transfer are conducted, and wherever iron plates are enamelled.

The beautiful glaze on chinaware and its colouring have hitherto been mostly obtained by the use of carbonate of lead, and the workers in these processes suffer considerably from lead poisoning. The use of the less soluble "fritted" lead—that is, lead fused into a kind of glass (a silicate) which is ground down and mixed with water—is attended with far less danger to the workers. It is stated that it is even safer to employ a double silicate of lead, which is more insoluble than the silicate. It appears, moreover, that the use of leadless glazes gives equally satisfactory results in ordinary white and cream-coloured ware; and experts have expressed the view that for seven-tenths of the total output leadless glazes can be used. No glaze can now be used which yields to a dilute solution of hydrochloric acid (0·25 per cent. of acid, the same acidity as that of human gastric juice) more than 5 per cent. of its dry weight of soluble lead, calculated as lead monoxide. Higher percentages of lead are allowed on condition that the employer adopts a scheme of compensation for those of his workpeople who suffer from lead poisoning, such workpeople being aware of the risks they run, and agreeing to face such risks.

In 1906 lead poisoning was made an industrial disease qualifying the worker for compensation.

Regulations have been issued by the Secretary of State for the smelting of materials containing lead, the manufacture of red and orange lead, and the manufacture of flaked litharge. Lead material means material containing not less than 5 per cent. of lead, and zinc material containing not less than 2 per cent. of lead. Where a lead

process is carried on which gives rise to dust or fume, the floor of the room must be kept in good condition and sprayed with water daily. Flues are not to be entered until they have been ventilated, and no person must work therein for more than three hours without an interval of at least half an hour. No person under sixteen years of age and no female shall be employed in any lead process. Suitable meal rooms and vestiaries must be provided with adequate washing appliances. There is to be a monthly medical examination of the workers, either by the certifying factory surgeon, or by some qualified medical practitioner appointed by the Chief Inspector of Factories to discharge temporarily the duties of the certifying surgeon, and, like him, to make examinations and give such certificates as are required under the Workmen's Compensation Act in regard to cases of industrial disease.

PHOSPHORUS POISONING is experienced among match makers. Makers of phosphor-bronze and the old-time vermin killer have also suffered. The phosphorus is obtained from bone ash, and serious nuisance and harm to the workers will result unless every proper precaution is taken. During the distillation of the impure phosphorus, dangerous gases are evolved.

The red or amorphous phosphorus is largely used in the manufacture of safety matches, the phosphorus mixed with glue being contained in the rubbing surface on the box. The igniting material is composed of chlorate of potash, iron pyrites, peroxide of manganese, powdered glass, sulphide of antimony, and an adhesive agent—generally glue.

Sanitary Precautions.—1. The discontinuance of the use of the dangerous yellow phosphorus, which is volatile at ordinary temperatures, and the employment of the red phosphorus for safety matches only. A harmless "strike everywhere" match can now be made from the sesquisulphide of phosphorus.

2. Frequent medical inspection, especially of the teeth. It is found that workers with sound teeth are practically exempt, but workers with carious teeth are specially prone to poisoning by phosphorus and to the onset of "phossy jaw" (caries of the jaw bones).

3. The selection of the workers.

4. Every facility for the practice of extreme personal cleanliness. Alkaline mouth washes should be used.

5. Large, specially well ventilated workrooms, and when possible the work should be performed in the open air. This precaution greatly reduces the amount of phosphorus poisoning. All fumes should be drawn away from the worker by means of efficient extraction fans.

6. No food or drink to be taken in the workrooms.

7. Short shifts of work, especially of those employed in the more dangerous rooms. Charcoal respirators should be worn by those engaged in the worst rooms—*i.e.*, where the dipping of the wooden heads of the matches in the phosphorus paste is performed.

8. The employment of machinery for dipping, drying, and boxing matches, as now installed in some manufactories.

The most dangerous factor in the whole process is the escape of fumes of the lower oxide of phosphorus (P_4O_6) from the moist heated paste.

The oxidizing effect of the vapour of turpentine is recommended as advantageous. The atmosphere may be impregnated with these vapours by exposing turpentine in saucers about the room, or on sponges hung round the necks of the workers, so that the vapours rise up into the air as it is respired.

The phosphorus should always be stored carefully in glass or earthenware vessels surrounded by water, and away from the workrooms.

The sulphur employed must not be overheated, or there is danger of ignition and the development of large quantities of SO_2. The pans in which the sulphuring is done should be covered, and the fumes conducted to a tall chimney.

The symptoms of chronic phosphorus poisoning are anæmia, anorexia, headache, emaciation, cutaneous and muscular hyperæsthesia, muscular pains and weakness. In those exposed to fumes, there may occur pain and swelling of the gums, followed by abscess and, later, necrosis of the jaw bone ("phossy jaw"). Persons exposed to phosphorus fumes are said to be liable to bronchitis and to spontaneous fracture of the long bones.

As to the causation of chronic phosphorus poisoning, the most probable theory (Lorinser) appears to be that the blood becomes surcharged with phosphorus, which in turn has a special affinity for bone, and as a consequence weakens the resistance of that tissue to local injury—this local injury in the case of the jaw bone being supplied through the medium of a carious tooth. Such necroses occur only after the worker has been for some years engaged in the work, and the necessary constitutional changes have been induced.

MERCURIAL POISONING.—Those exposed to the poisonous effects of the vapours are mainly the makers and users of vermilion pigment from cinnabar and of imitation bronzing, barometer and thermometer makers, and the gilders working with mercurial gold amalgam. The former great source of industrial mercurial poisoning—the silvering of mirrors by means of an amalgam of mercury and tin—has ceased, the process having been superseded in this country by the nitrate of silver and ammonia process. The workers in factories where calomel, corrosive sublimate, and the red oxide of mercury are prepared, hatters, furriers, and the makers of electric meters and electric lamps, also suffer. Furriers brush the fur with a solution of the acid nitrate of mercury.

The symptoms of mercurial poisoning are insidious in their onset. They are anæmia, tender gums, often salivation, diarrhœa, tremors of the face, arms, and hands; the teeth frequently fall out. Mercurial poisoning appears to predispose to phthisis, and to be predisposed to by alcoholism.

The sanitary precautions necessary are similar to those already indicated where poisonous fumes and dust occur; but it is important to observe that the mercury should be kept covered over as much as possible, so as to limit the diffusion of the vapours, especially in

hot workshops. The diffusion of the vapours of ammonia throughout the workshops when these are temporarily vacated is highly spoken of. The floor of the workshop should be such as to admit of a thorough collection of all spilt mercury at the end of each working day.

A very important preventive measure is care of the mouth and teeth, and the removal or filling of carious teeth. All cases of mercurial poisoning must be notified to the Chief Inspector of Factories.

Arsenic poisoning.—In the following trades the workers are liable to arsenic poisoning: The makers of articles coloured with arsenical dyes (carpets, dresses, artificial flowers, etc.); those who prepare skins of animals for stuffing; the makers of sheep dip, arsenical paints and dyes, such as "emerald green." This salt is also used for the destruction of the insect pests which destroy fruit trees and potatoes, and the mining and smelting of arsenical ores. It was formerly the chief cause of arsenic poisoning; but the adoption of methods involving no handling of the material has much reduced the danger.

The sanitary precautions necessary are very similar to those which should be practised against lead poisoning. Arsenical colours and dyes are unnecessary, and their use should be prohibited. No water from the works containing waste arsenic should be allowed to enter a stream.

Copper poisoning.—Copper miners and smelters sometimes suffer from poisoning.

In brass foundries the workers (more especially the turners, polishers, and filers) inhale a metallic dust which is productive of a disease formerly called "brass founders' ague." The symptoms which caused Dr. Greenhow to designate the disease brass workers' ague are shown to be due to the ingestion of a quantity of the irritant metallic dust sufficiently large to cause vomiting with its attendant depression. Brass is an alloy of copper and zinc, in the proportion of about three to one. Probably the zinc is the offending ingredient, though possibly the copper may have some additional influence. The symptoms are described as tightness and oppression of the chest, with indefinite nervous sensations followed by shivering and profuse sweating. The illness only occurs in those who are new to the work, or who resume work after an absence of a few weeks. The men who suffer in this way drink freely of milk and promote vomiting, the best treatment that could be devised for copper or zinc poisoning.

Copper poisoning is also found amongst brass workers, and bronchitis from inhalation of the irritant dust. The leading symptoms of chronic copper poisoning are: Anæmia, nausea and vomiting, colic, wasting, headache and nervous symptoms, and a green line (due to copper) is seen at the bases of the teeth. The patient also suffers from profuse sweatings which stain the underlinen a greenish colour, itching, skin eruptions, chronic bronchial catarrh, and later pulmonary fibrosis. For the prevention of brass founders' ague "special rules" are enforced by the Chief Inspector of Factories. These rules apply only to the casting and mixing shops, and require that adequate means be provided for the escape of noxious fumes and dust,

that the shops be cleaned down and limewashed every year, that the workpeople have every facility for personal cleanliness, and are prohibited from eating during the process of casting. The inhalation of fumes and dust must be avoided by suitable ventilation arrangements and respirators.

Chromium poisoning.—Chrome colours are largely used by dyers, chiefly as yellow, orange, and red colouring agents, but aniline dyes are now taking their place. The chief symptoms of poisoning (from swallowing chromium) closely resemble those of Asiatic cholera. The effect of the chromates of potash on the skin and mucous membranes exposed to their action is to cause destructive ulceration, the nasal mucous membrane being especially liable to suffer from the lodgment of the fine dust resulting from the grinding of the chromates. Those who break up and pack the chromate crystals suffer most.

The sanitary precautions which are necessary can be gathered from what has already been said with reference to lead.

Various forms of eczema and ulceration may be set up by irritants used in the technical arts and crafts. Of these, bichromates, aniline, arsenic materials used by potters and laundresses, flax, strong alkalies, acids, and other chemicals are the most important. Often the lesions in the mucous membranes are more distressing than those of the skin. The handling of tar often causes eczema.

Antimony poisoning.—Chronic antimony poisoning has been observed among workers in chemical industries and among paint makers exposed to dust from antimonial salts.

Manganese poisoning.—Well-defined symptoms of poisoning have occurred among certain workers engaged in the manufacture of chlorine and oxygen, dyeing, colouring glass, charging electric batteries, the making of lacquer and oil paints.

Sulphurous acid may find its way into the atmosphere from a large number of industries: the manufacture of sulphuric acid, alum, and glass, the tinning of iron, bleaching works of certain kinds (wool, cotton, silk, straw, etc.), the preparation of hops, and the burning of coal rich in pyrites, etc. This irritating gas may give rise to bronchitis and anæmia.

Chlorine may gain access to the atmosphere from bleaching and dyeing works. It causes acute catarrh, acute pneumonia, conjunctivitis, pyrosis, and indigestion. Respirators kept moist with sodium hyposulphites are recommended as a protection.

Sometimes where dangerous fumes such as *nitrous fumes* get into the air, air or smoke helmets are required to be worn by the workers; these are connected up with compressed air mains which supply the helmets with air through taps provided with suitable pressure-reducing arrangements.

Bisulphide of carbon gets into the atmosphere of vulcanized india-rubber works, the liquid being used as a solvent of gutta-percha. The symptoms of poisoning are serious.

In the manufacture of Portland cement traces of compounds of cyanogen are given off during the process of burning.

Carbonic acid is given off in large quantities from lime burning,

breweries, paper-mills, sugar and starch factories, etc., and is often present in excess in the air of aerated water manufactories.

It causes debility, loss of appetite, drowsiness, and nervous derangements, and when present in great quantities causes dyspnœa, muscular debility, and coma; and, if death results, the heart and lungs are filled with dark blood. Well sinkers are occasionally asphyxiated by the large amount of this gas which collects in deep shafts.

In CARBONIC OXIDE POISONING, on the other hand, there is no dyspnœa, coma is slight or absent, there is drowsiness followed by loss of consciousness, convulsions may occur, and the blood is bright, with a bluish tint.

Less than 0·3 per cent. of CO in the atmosphere may cause unpleasant if not serious symptoms.

The symptoms of chronic poisoning are not very definite. There may be headache, sickness, diarrhœa, impaired digestion, a dry throat, physical and mental depression, and anæmia. Those most liable to CO poisoning are the workers at coke ovens and brick kilns, limestone workers and cement workers, coal miners after explosions of fire damp, coal gas makers (from escapes of gas), distillers of coal tar, lampblack makers, and iron smelters. CO is also liable to be present in the air of laundries where the irons are heated over flueless gas stoves, and poisoning may result from escapes of suction, producer, Mond or Dowson gas, where these are made and employed.

On the Rand, where compressed air is largely used for drilling and for ventilation, a number of deaths from CO poisoning have resulted from the overheating of the air compressor and the firing of the oil employed for lubricating the cylinders. It is recommended that only oil of very high flash-point should be used for such purposes.

When in the case of petrol engines the ratio of petrol to air is badly adjusted and becomes excessive, there is incomplete combustion, with the result that the percentage of CO_2 in the exhaust decreases, while that of CO increases, and may even reach 12 to 15 per cent. Cases of poisoning have occurred from exhaust gases from petrol engines when the exhaust has not discharged into the open air. Men have suffered from symptoms resembling migraine or have been rendered unconscious by the entrance of exhaust gases into closed motor vehicles; and chauffeurs have similarly suffered from the exhaust in poorly ventilated garages.

In all cases of CO poisoning the patient should be placed in the open air and artificial respiration performed, if the breathing is feeble or absent. If available, oxygen should be administered for half an hour (longer is useless), and the patient kept warm. Although the attraction of hæmoglobin for carbon monoxide is so much greater than for oxygen, the effect of artificial respiration of pure air and oxygen administration is gradually to displace the CO from its combination with the hæmoglobin of the blood corpuscles.

Several fatal accidents have resulted from the carrying of FERRO-SILICON as a cargo on ships and barges. This material is used in the manufacture of certain grades of steel, and is an alloy of iron and

silicon. The low grade variety, containing not more than 15 per cent. of silicon, is made in blast furnaces in this country; while the high grade classes, containing from 25 to 95 per cent. of silicon, can only be made in the electric furnace, and are largely imported from the Continent. Ferro-silicon of grades under 30 and over 70 per cent. would appear to be innocuous (Copeman), but grades between 30 and 70 per cent. give off poisonous emanations, the chief poisonous gas being phosphoretted hydrogen, along with a small quantity of arseniuretted hydrogen. In a report of the Local Government Board on ferro-silicon (1908-09), it is recommended that only the non-injurious grades should be used in steel manufacture, but that if the injurious grades are used, they should be exposed to the air, but under cover, for at least a month before transit; that no passenger boats should be used to convey them; and that storage places at docks or works should have free provision for access of air, and should not be near workrooms or offices.

TRINITRO-TOLUENE.—This is a high explosive obtained by nitrating toluene—a product of coal tar distillation. Operatives employed in the manufacture of this substance in munition factories, and in loading it, have been found to be affected with unusual drowsiness, frontal headache, certain skin rashes, and loss of appetite. In exceptional cases sudden collapse may occur after a few hours' work on a hot day, but generally the symptoms are at first slight and quickly disappear if the workers are relieved. If the exposure is continued, symptoms become more severe, and may be associated with circulatory, respiratory, and alimentary troubles.

TNT may be absorbed by the skin, or dust and fumes may be inhaled or swallowed. It stains the skin and hair of the worker a characteristic tawny orange colour, and dermatitis with much irritation is common on exposed parts. Fatal jaundice may make its appearance some weeks after entire cessation of association with the industry, and acute yellow atrophy of the liver is present in fatal cases. Milk albumin, or preferably sanagen, is useful as forming an insoluble picrate with the toxic element.

In 1915, the Ministry of Munitions issued a series of Regulations for factories in which TNT and other poisonous explosives are manipulated. Under these Regulations it is required that every worker shall be medically examined at least once a fortnight; that every worker shall wear a washable costume to be renewed at least once a week, and which may, with advantage, be cleaned daily in a vacuum cleaner; the washing accommodation and provisions for workers must be the same as those provided for by the Home Office under the Factory and Workshops Act; all food must be consumed in a canteen or other approved place; the employer must provide daily one pint of milk, or cocoa made with milk, to every worker; the employer is required to take all practical means to prevent the accumulation, production, and dispersion of dust; and the operations of filling TNT bags must be isolated from other operations. Wherever practicable, no worker should handle the material for more than a fortnight without a corresponding period of work which does not involve contact with TNT or other poisonous dusts. Certainly some

workers are more susceptible than others to the effects of this substance.

"TETRA-CHLOR-ETHANE has formed an ingredient of the 'dope' varnish applied to the canvas coverings and tapes of aeroplane wings, and to aeroplane bodies, in order to render them impervious to moisture and air. Inhalation of this vapour, even in small amounts, when spread over prolonged periods, has caused drowsiness, headache, giddiness, vomiting, loss of appetite, and pains in the stomach; and in more serious cases, jaundice, liver destruction, coma, and death. The methods of prevention which have been recommended are: adequate exhaust ventilation near the floor level; the prohibition of operatives remaining in the workplace during meal hours; the reduction to a minimum of the period of exposure of workers; the alternating of the process of 'doping' with other work; and the periodical medical inspection of workers, with power to suspend any affected persons from such employment. An apparently effective varnish has recently been found which does not contain these poisonous matters."

Other irritating and harmful gases and vapours are:

ACETALDEHYDE.—Developed in connection with the making of vinegar.

ACROLEIN.—Given off in various fat industries.

AMMONIA.—Used in many manufactures, cleaning processes, refrigerating plant, etc.

SAL AMMONIAC.—Used in galvanizing zinc.

PHOSGENE OR CARBON OXYCHLORIDE.—Forms hydrochloric acid in the lungs.

ANILINE.—A highly toxic volatile substance derived from the distillation of coal-tar. Nervous symptoms and cyanosis are produced.

BENZENE AND NAPHTHA.—Used in dry cleaning, dyeing, the making of rubber goods, and employed in quick-drying paints. Nervou symptoms predominate.

PRUSSIC ACID may be inhaled in the developing of photographs, the making of coal gas, red prussiate pigment, fulminate of mercury, and in electro-plating. The acid forms a fixed compound with the hæmoglobin of the blood.

VANADIUM.—The salts of vanadium are employed in photographic developing solutions, calico printing, and the manufacture of malleable ductile steel. The wearing of cloth dyed by the vanadium process has been known to cause toxic symptoms.

NITROBENZOL and DINITROBENZOL are employed in the production of high explosives and aniline. The vapour when inhaled is absorbed, and forms droplets in the blood which act as emboli; and there may be absorption through the skin. Circulatory and nervous symptoms predominate in nitrobenzol poison, and in dinitrobenzol poisoning the mucous membrane of the mouth and the urine are stained yellow and the breath acquires an odour of bitter almonds.

The material should never be touched by the hands, clothing should be changed before leaving work, and the hands and face washed. Shoes should be kept in perfect order, as absorption might occur through the feet of material on the floor.

It is necessary, so far as possible, to collect the above-mentioned fumes at the points where they are produced, and to condense or absorb them so that they may be safely disposed of.

Notes upon other Industrial Diseases.

Arterio-sclerosis.—One of the commonest of all the lesions of the diseases arising from occupation, particularly among workers with the poisonous metals, and those whose occupation involves much strain of the circulation, as in the lifting of heavy weights, is arterio-sclerosis, with its resulting cardiac hypertrophy. It is not uncommon among painters.

Cancer.—Epitheliomatous ulcerations occurring in industries dealing with tar, pitch, and paraffin are now compulsorily notifiable by order of the Home Office. The recognition of the peculiar liability of workmen in these trades to skin cancers as a result of their occupation allows not only of the recognition of the earliest signs of tumour growth and consequently the prompt use of remedial means, but also of the institution of preventive measures against their occurrence.

Nystagmus.—The workers in coal mines are liable to a condition of the eyesight which has been termed "miners' nystagmus." This is essentially a disease of the collier, but is unknown among the younger miners. It was first described at the time when the illumination in collieries was considerably reduced by the introduction of the Davy safety lamp. The evidence collected points to the conclusion that the condition is not caused by awkward positions of the body and strain of the eye muscles, but is mainly due to feeble illumination in the mine. With an improvement in the lighting and shorter hours of work in mines, the incidence of the disease shows a tendency to diminish.

Dr. D. L. Anderson considers the great predisposing cause to be errors of refraction, and he proposes that a standard of vision should be fixed for underground workers.

It is only in a small proportion of the workers that the condition becomes so severe as to cause incapacity.

Cataract.—This condition is specially liable to develop among glass workers and others exposed to molten and red-hot metals. Prevention may be assured by the use of spectacles provided with Crookes's glass.

Deafness.—Occupational deafness is most in evidence among persons employed as boiler makers, owing to the loud hammering which is maintained. Where the noises are very great and continuous, workmen are recommended to plug the ears with plasticine worked into cotton.

Industrial Dermatitis.—The paraffin workers of the Scottish shale industry are liable to skin lesions (dermatitis, paraffin-workers' cancer) due to contact with oily paraffin in a crude or a semi-refined state.

The position of industrial dermatitis may be briefly summarized as follows: (1) Oils of all types and other fat solvent fluids are liable, if they come in contact with skin for some time, to produce der-

matitis; the underlying cause is desiccation with subsequent cracking of the skin. (2) The exact form of dermatitis which results depends on the infective organism or organisms which obtain access. (3) The organisms are not usually present in the oil, but exist on the human body; therefore, the dirtier the skin, the more readily is it infected. (4) Prevention depends first upon cleanliness, and secondly upon restoring the dissolved fat by anointing the skin with such a mixture as equal parts of lanolin and castor oil. (5) Treatment consists in removal from exposure and entire rest to the affected skin by covering it with a flexible paint, such as is used in treating burns.

Industrial Anthrax.—This disease has claimed many victims among industrial workers.

The dangers of industrial anthrax arise in connection with imported hides, hair, and wool. Such material from China, Persia, East India, Russia, and Africa is the most dangerous, and the infection is associated with blood and blood clots to a marked degree.

Regulations of the Secretary of State require that the most dangerous bales of wool or hair (as scheduled) must either be steeped in water before being opened, or steeped or opened over an efficient opening screen with mechanical exhaust draught in a special room, or sorted over a board provided with a downward exhaust draught, according to the material dealt with.

Only skilled operatives to open such bales of wool or hair.

Damaged material must, when opened, be damped with a disinfectant and washed without being willowed. Scheduled articles may only be willowed in an efficient machine in a special room, and may not be stored in a sorting room, unless a space effectually screened off from a sorting room; 1,000 cubic feet of space must be provided for each worker in a sorting room, and suitable ventilation provided.

All pieces of skin, scab, and clippings must be removed daily from sorting room and disinfected or destroyed, and the dust collected must be received into suitable receptacles. This dust, together with sweepings of different rooms, to be removed twice weekly and burned.

Extracting shafts and spaces beneath sorting boards and opening screens to be cleaned out at least weekly.

Operatives engaged in dust collection and removal must be provided with overalls and respirators. Such overalls to be steeped overnight in boiling water or a disinfectant, before removal from works.

Floors of working rooms must be sprinkled daily with a disinfectant solution at end of day's work, and swept immediately afterwards. Walls and ceilings to be limewashed once a year, and cleansed at least every six months.

Suitable and sufficient washing accommodation and suitable and sufficient meal-room accommodation must be provided.

No person having an open sore or cut may be employed.

Those employed in a room in which unwashed wool or hair (as scheduled) is stored or handled must wash their hands before taking food or leaving the premises; must wear overalls while at work, removing them before taking food or leaving; and must not deposit

any article of clothing removed in any such room; and they must report any open cut or sore.

The sorting board shall comprise a screen of open wirework, and beneath it at all parts a clear space not less than 3 inches in depth. Below the centre of the screen there shall be a funnel, measuring not less than 10 inches across the top, leading to an extraction shaft, and the arrangement shall be such that all dust falling through the screen and not carried away by the exhaust can be swept directly into the funnel. The draught shall be maintained in constant efficiency whilst the sorters are at work, and shall be such that not less than 75 cubic feet of air per minute are drawn by the fan from beneath each sorting board.

The Secretary of State has since added toxic jaundice, epitheliomatous ulceration, and chrome ulceration, contracted in a factory or workshop, to those diseases which are required to be notified to the Chief Inspector of Factories by the Factory and Workshops Act, 1901—viz., lead, copper, arsenic, and phosphorus poisonings, and anthrax.

Under special rules issued by the Home Office, periodical medical examination of workers in dangerous processes, either by the certifying factory surgeon or other medical practitioner, is required in the following industries: white lead works, china and earthenware works, the manufacture of litho-transfers, enamelling of iron plates, electrical accumulator works, the manufacture of explosives in which dinitro-benzol is used, and bichromate factories; in lucifer match factories where yellow phosphorus is used periodical examination of the teeth of the persons in certain specified processes is enjoined. Further, in paint and colour factories, in chemical works where pharmaceutical mercurial preparations are made, in hatters-furriers' processes where mercury nitrate is used, etc., voluntary periodical examination is in some cases provided.

Notes on Marine Hygiene.

The maintenance of health on ships must obviously depend upon the application of the same general principles that apply on shore, although some modifications of practice are often demanded owing to the different conditions that exist on board ship.

Crew's Quarters.—In the great majority of vessels the crew's quarters are situate in forecastles in the forward part of the ship. This situation is objectionable, as the bows of a ship are most exposed to strain, stress of weather, and danger, and the difficulty of ventilation in bad weather is very great. The best situation for the crew is in deckhouses aft, where ventilation by natural means is possible.

Crew Space.—The space provided under the Merchant Shipping Act, 1906, gives 120 cubic feet and 15 superficial feet per man. In Australia 140 cubic feet and 18 superficial feet has been adopted. It is very desirable that the spaces required above should be afforded as sleeping accommodation, and that a separate messroom and ablution room should be provided additional to the space for sleeping, but these are not obligatory under the Act.

Sleeping Quarters.—In the larger vessels cubicles should be

provided, each to accommodate two men, in two bunks one above the other, the lower being 2 feet from the floor, and the upper 2 feet above the lower. The bunks should be of iron, without any woodwork, so as not to harbour vermin. They should not be placed so as to touch the ship's side, in order to avoid the dripping of condensed moisture from the ship's side on to the bunks. In iron ships the exposed iron should be coated with cork and distempered to prevent condensation of moisture and dripping. The bunks should be 6 feet 6 inches long by 2 feet 3 inches wide, with spring copper wire bottoms and iron top and side rails. They should be made collapsible or capable of being folded up by a hinged joint, and should be removable for cleansing. By this means the seamen are given more room when the bunks are not in use.

Ventilation.—In small vessels natural ventilation can usually be obtained through ports and cowls, especially in the case of deck-houses situated aft of the ship. Electric fans should be provided wherever possible, to create air currents and prevent stagnation of atmosphere. In the larger vessels, where there is steam power available, systems of ventilation by extraction and propulsion, or a combination of both, are possible by the use of steam or electric-driven fans, and such systems are now very general. These systems should be used for the ventilation of the crew's quarters, as well as for other parts of the ship.

For merchant ships the Board of Trade issues instructions which are of a very general character. Constant circulation of fresh air should be kept up by means of iron pipes fitted with revolving cowls at each end of the space to be ventilated. For the tropics means of introducing windsails are insisted on. Where mechanical ventilation is contemplated, the plans are first to be submitted to the Board's surveyor. In many cargo steamers, however, the ventilation leaves much to be desired, as natural means of ventilation render the men's quarters cold, and during bad weather have often to be closed to exclude sea water. In the navy and large liners, some mechanical system of ventilation is employed, the Royal Navy most frequently selecting the plenum system. The exhaust system is often applied to places where great heat and vapour, foul odours, or dangerous gases are generated.

Cubic Space.—It is laid down by the Merchant Shipping Act that each man shall have 120 cubic feet of air space and 15 square feet of floor space. These amounts cannot be regarded as adequate, particularly in their application to messrooms, bathrooms, and washing places. The standard of the Royal Navy is 200 cubic feet per man for sleeping accommodation; not for messrooms and ablution rooms. The spacing between hammock hooks is 20 inches.

Sleeping Quarters.—Hammocks, properly spaced and slung, have been regarded as satisfactory. The fixed bunks found in many cargo ships are extremely insanitary, as they cannot be cleansed thoroughly and readily harbour vermin. Collapsible iron bunks on a cubicle system should be provided, and these should not be close up against the side of the compartment; this ensures a better circulation of air and renders cleaning easier. Woodwork should be avoided,

as it tends to harbour vermin. To render iron walls warmer and less ready to condense moisture, cork paint is often employed.

Heating.—In small vessels the warming of the crew's quarters is usually effected by means of stoves. The stove should have a corrugated iron body with an internal lining of fireclay tiles, to prevent cracking and the escape of fumes. An inlet ventilating shaft with movable funnel inlet should surround the smoke flue for the provision of warmed fresh air to the quarters. In larger vessels with steam appliances, the quarters can be best heated by steam radiators, or by heated air from a thermo-tank system, but this latter is less healthy than heating by radiators with the introduction of fresh cool air by a plenum fan system.

Lighting.—Daylight is usually admitted by port-lights, deck-lights, or skylights with very thick glass. Electric light is the best for artificial lighting.

Lockers and Cupboards.—Food cupboards and clothes lockers for wet clothing should be provided outside the sleeping quarters. The food cupboards should be lined with zinc, and suitably ventilated with louvred sides and doors, the openings being covered with wire meshwork to exclude flies.

Closets.—There should be separate pedestal basins of short hopper type, connected to a pipe opening directly overboard. The basins should be of enamelled iron or strong glazed stoneware. The flushing should be by an automatic flush tank connected to the flushing rims of the basins; or, on steamers, a continuous flow of sea water can be maintained by the use of the donkey pump. For Lascars and Chinese crews special latrines consisting of a channel in a cement floor opening to the sea by an escape hole should be provided, the channel being automatically flushed with water.

Ablution Rooms.—These should be provided, and fitted with shower baths in addition to wash basins. The floors should be of cement, or covered with impermeable litho-silo floor covering. Scupper channels should be provided to keep decks, ablution rooms, and water-closet compartments dry.

The victualling of ships has always been a matter of great difficulty, and ignorance and lack of care in the selection of stores and the suitable storage of food have been responsible for much ill-health. The provision of a varied diet, containing an adequate amount of fresh food, is now recognized as essential. Captain Cook, in 1776, pointed out the need for fresh lemons and vegetables, and his recommendations have since been scientifically justified. Food scales are laid down for emigrants and steerage passengers by the Merchant Shipping Act, 1906.

Water Supply.—Small galvanized iron tanks connected internally with a manhole for cleansing are better on small vessels than wooden casks pitched inside. Vessels undertaking long voyages should be provided with some form of filter, such as the Pasteur-Chamberland, or other sterilizing outfit (chlorination is carried out in the navy), except where distillation of sea water is undertaken.

Ships rely for their water supply either upon distillation or on the storage of water obtained from shore. The former method is the safest, but here also care should be taken that the sea water to be

distilled is obtained from a pure source in order to obviate the carrying over of volatile polluting matter. Those ships obtaining their water from the shore do so either directly from pipes on the quay, or by the agency of water tank boats. The tanks of these water boats must be protected against the action of the water, and, like the water tanks in which the water is stored on board ship, be cleansed at regular intervals. The men employed in this work should be carefully supervised and medically inspected before such duties are imposed upon them.

Hospitals.—In Great Britain a hospital on board ship is optional except on emigrant vessels. It should, however, be provided on all large vessels. A room should be provided with accommodation for two persons at least, as much isolated as possible from the rest of the ship. A small disinfecting apparatus is a useful adjunct.

Disinfection and Fumigation of Ships.—Sulphurous acid gas is extensively used for these purposes. The Clayton disinfecting and fumigating machines are frequently employed (*vide* pp. 728 and 729). Sulphurous acid gas in liquid form has also been used for the destruction of rats and other vermin, such as bugs, fleas, and cockroaches. Sulphurous acid is preferred in this country to hydrocyanic acid gas or the use of carbon monoxide, because of the less elaborate precautions which have to be taken to guard against dangers to human life. It is generally found necessary to pull down woodwork prior to fumigation where the destruction of bugs is necessary.

Cattle Boats.—The animals should be placed athwart the ship, and tied by the head with ropes. The deck should be provided with battens so as to afford a good foothold, and covered with sand of sawdust. A passage-way 18 inches wide is provided on each side of the centre line, with cross-passages, so that the animals may be properly tended. The foul air should be extracted by exhaust fans. There should be channels between the sets of battens to carry off liquid filth to scupper-holes in the side of the vessel, if above the water-line. Below the water-line, the liquids must be absorbed by sawdust. On reaching port, the heavy manure should be sprayed with hot lime before removal. The decks should be hose-washed, the liquid running out through the scupper-holes; and the pens and fittings should then be thoroughly sprayed with hot lime-wash.

In 1918 a definite hygienic branch of the Royal Navy was established by the appointment of the Naval Health Officer. The duties of these officers are comparable to those of a Port Medical Officer of Health in relation to the naval population and its areas of distribution. They act as liaison officers of health, connecting up with the military and civil health officers of the ports and districts.

The Port Sanitary Authority.—A port sanitary authority discharges duties under public health legislation which are very similar to those performed by urban sanitary authorities. The port sanitary authority has not full control in matters affecting the sanitation of vessels, as the sanitary provisions of the Merchant Shipping Act, 1894, are not administered by them, and ships belonging to British and foreign Governments are exempt from their inspection.

The port sanitary authority exercises its powers under the following Acts, Orders, etc.: (1) The Public Health Act, 1875, and the Public Health (London) Act, 1891, under which any ship or vessel lying in any river, harbour, or other water within the district of the local authority, is subject to the same treatment with regard to nuisances as premises on land; (2) the Public Health (Ships) Act, 1885, which extends to ships the provisions of the Public Health Act, 1875, which apply to hospitals and infectious disease; (3) the provisions of the Infectious Disease Notification Act, 1889, which are applicable to ships; (4) the Public Health Act, 1896, which repeals the Acts relating to quarantine, and defines the powers of the Local Government Board to make Regulations. These Regulations (1907) require that infected ships must hoist a yellow and black flag, which must be displayed between sunrise and sunset when within 3 miles of the coast, and three lights arranged as a triangle, the apex light being white and the two lights at the ends of the base of the triangle red, between sunset and sunrise.

A place must be appointed for the mooring of all infected ships, and when the Customs Officer finds or suspects that a ship is infected he must order the ship to be anchored in this place and acquaint the sanitary authority of the fact, when none of the passengers or crew may leave the ship; the Medical Officer of Health must visit and inspect within twelve hours, or the ship may proceed; and if he is of opinion that any ship is infected, he must certify to the master of the ship and the sanitary authority and inform the Local Government Board; the master must moor to an appointed "mooring place," where the Medical Officer of Health shall examine every person on board; and no one may leave the ship.

Infected persons must be removed to a hospital, or the ship may be constituted the hospital; suspected persons may be detained on board or in hospital for forty-eight hours; other persons shall satisfy the medical officer as to their names, places of destination, and addresses at such places, and the clerk to the sanitary authority must transmit this information to the sanitary authorities of the districts to which such persons are going; every person who, within forty-eight hours after landing, shall arrive at any other address than that furnished, must notify in writing his fresh address to the Medical Officer of Health of the district in which such place is situate.

The master, under the direction of the sanitary authority, must bury infected dead bodies (properly loaded) at sea, or deliver to sanitary authority for burial; all necessary disinfection is to be carried out at the cost of the owner and to the satisfaction of the Medical Officer of Health; bilge water, and water that may be ordered to be pumped out before the ship (whether infected or from an infected port) enters a dock or basin, and all casks or tanks containing drinking water are to be emptied and cleansed if required.

On ships *infected* with plague, the rats *must* be destroyed either before or after the discharge of cargo, within a maximum period of forty-eight hours; and where the infection is yellow fever, appropriate measures must be taken for the destruction of mosquitoes and

their larvæ. Precautionary measures shall be adopted at infected ports on the departure of vessels, and the Local Government Board has made regulations as to this.

For the purpose of administering these powers the port sanitary authority shall appoint a Medical Officer of Health and Sanitary Inspectors. In a large port the services of one or more assistant medical officers are generally required, especially when cholera or plague threatens; the medical officers then take duties in rotation.

In the sanitary inspection of ships the following matters claim attention: the condition of the crew's quarters with regard to ventilation, lighting, cleanliness, and protection from weather; cubical capacity and floor areas (there should be a minimum of 120 cubic feet and 15 square feet of floor space for each man); general cleanliness; the efficiency of sanitary fittings and the condition of the bilges and bilge water; the source of supply and storage of drinking water, the accessibility for cleansing purposes and the protection of tanks, etc., from contamination. The inspection of foodstuffs brought to the port, and their seizure when unwholesome or unfit for the food of man, is an important branch of port sanitary work.

The work of checking the spread of infectious disease aboard and preventing its importation is another important branch of work. It is performed in precisely the same manner as on shore, as is also the subsequent disinfection. Copies of the regulations relating to various infectious diseases are printed in several languages and distributed among ship-owners, consuls, captains, and all interested; and detention houses should be provided in ports of entry for immigrants.

By-laws relating to infectious diseases have been made by nearly all port sanitary authorities. These require, *inter alia*, that:

A vessel arriving with *any* person on board suffering from a dangerous infectious disorder is required to stop at a certain specified place, and acquaint the Medical Officer of Health. The vessel shall remain there until boarded by the Medical Officer of Health, who may order the master to land the case at the hospital of the port sanitary authority, if proper accommodation can be provided therein.

By-laws may also be made for keeping in hospital, for so long as may be necessary, any persons, brought within their district by any vessel, who are infected with a dangerous infectious disease.

As the Customs Officers are the first to receive intimation of sickness on board any vessel approaching the port, it is desirable that the Customs Depot and the Port Sanitary Offices should be adjacent to each other, so that all information of infectious illness can be easily and promptly reported to the sanitary authority. The Port Sanitary Hospital should be well isolated and at a convenient distance from the mooring station. Commonly the City Fever Hospital is used for the reception of all sea-borne cases of infectious disease excepting cholera, plague, yellow fever, or small-pox.

When any vessel has had dangerous infectious disease aboard, the Medical Officer of Health must give notice thereof to the Medical Officer of Health of any port in the United Kingdom whither such vessel is about to sail.

Ship-borne Rats and Plague.

In view of the susceptibility of the rat to plague, and of risk therefore of importation into this country by shipping of plague-infected rats, sanitary authorities of seaports should be on the alert to prevent introduction of the disease into their districts in this way.

1. On the arrival in port of a vessel whereon, during the voyage, plague or sickness suspected to be plague has occurred, measures should be taken to secure the destruction of the rats on board the vessel. Until this has been done endeavour should be made to prevent rats leaving the ship, by mooring the vessel a sufficient distance from other ships and from the shore, and by placing guards on cables and hawsers in use for mooring purposes.

2. In the case of vessels that have come from places infected with plague, but on board of which no plague or suspected plague has occurred, strict inquiry should be made on the arrival in port as to mortality or sickness among rats during the voyage. Should this have occurred, the authority would do well to obtain the body of a sick rat for the purpose of ascertaining the nature of the malady affecting those animals on board the vessel. In the event of the malady being found to be plague, the ship should be dealt with as under Paragraph 1.

3. Exceptional sickness or mortality among rats on board any vessel within the district, whatever may have been her port of departure, should be viewed with suspicion and as giving occasion for action similar to that indicated under Paragraph 2.

4. Rats when destroyed on shipboard should not be handled; they should be at once cremated.

5. In the event of rats on board any ship being found to be infected with plague, all parts of the vessel frequented by those animals should, as far as possible, be disinfected.

6. The authorities of seaport towns invaded by plague should endeavour to secure the destruction of the rats of the town, specially those inhabiting the docks and quayside warehouses. Measures should be taken to guard against shore rats making their way on board vessels lying in the port, and an attempt made to destroy all rats on board ships about to proceed on their voyage. Captains of such vessels should be urged to take steps during the ensuing voyage for the destruction of rats that may have remained alive on board their vessels notwithstanding the action of the local authority.

CHAPTER XIII

DISINFECTION

As already mentioned, the virus of a contagious disease undergoes enormous multiplication in the body of the sick person, and is cast off during the period of illness in the mucous discharges and secretions, in the breath, and from the skin. The contagion infects the air around the patient, and infects the bedding, clothes, and furniture of the sick-room. Disinfection aims at the destruction of the virus in these various situations.

In the first place, it would be natural to suppose that the infective particles might be destroyed before leaving the body, or as soon as they are carried into the air; but chemical reagents strong enough to destroy specific micro-organisms would cause injury when taken into the system or when diffused into the air around the patient. Where the virus is only contained in the evacuations, as in enteric fever, these can be at once disinfected by chemical solutions; but in the case of the other common infectious maladies complete disinfection of a room and its contents is only possible when the patient is convalescent and no longer a source of infection himself.

No agent can be regarded as a *disinfectant* unless it is capable of destroying the organisms with which it is brought into contact; agents which merely inhibit bacterial growth and prevent decomposition are known as *antiseptics;* while others, such as charcoal, which oxidize or absorb odorous products, are termed *deodorants*. Liquid disinfectant preparations are preferable to solid, for they can be much more efficiently distributed; and until a solid disinfectant is in solution, it is powerless to act directly upon organisms. The final results attained in disinfection are greatly influenced by the nature of the material to be disinfected. Infectious organisms are always in association with a greater or less amount of other organic matter under natural conditions, and the practical question which has to be answered

is: What is the required strength of any disinfecting agent to ensure destruction of a given infection in its natural environment?

Since disinfectants are intended for the destruction of the germs of specific diseases, it has long been recognized that the only satisfactory method of judging their relative values is by ascertaining the actual strengths at which they must be employed in order to kill these germs under certain fixed conditions. It is true that bacteriologists have already determined the action of many disinfectants on a variety of micro-organisms, but owing to the employment by different observers of different methods, different organisms, and different standards of comparison, the discrepancy as to the relative value of disinfectants, that may be found in the literature on the subject, is most perplexing. What is wanted is a standard method of comparison that shall be both scientific and easily practicable, in which the various agents are tested side by side under precisely similar conditions. With this object Rideal and Walker have proposed that phenol should be taken as the standard disinfectant, and *Bacillus typhosus* as the standard germ in such tests. The suggested method of working is as follows:—To 5 c.c. of a particular dilution of the disinfectant in sterilized water are added 5 drops of a 24 hour blood-heat culture of *B. typhosus* in broth; after thorough admixture, sub-cultures are taken every $2\frac{1}{2}$ minutes up to 15 minutes, and these are incubated for at least 48 hours at 38° C. The temperature during medication should be from 15° to 18° C., and the standard broth employed should have a reaction of +15. The strength or efficiency of the disinfectant can then be expressed in multiples of carbolic acid, as follows: a dilution of the disinfectant being obtained which does the same work as the standard carbolic acid dilution, the former is divided by the latter, and thus a ratio is obtained which is called the "carbolic acid coefficient." The method is useful as one upon which it may be found possible to base a practical test; but it does not tell us of the strength at which the various disinfectants must be employed in actual practice, because it does not take into account the influence of the associated organic matter upon the potentialities of the disinfectant. In other words, we have not in practice to disinfect the typhoid organism in a broth culture, but the organism implanted in fæces and urine, and often more or less protected from chemical disinfectants by surrounding organic matter.

In the Martin-Chick (Lister Institute) test for the standardization of disinfectants for practical purposes, the temperature for medication is fixed at 20° C., an interval of 15 minutes is allowed for the disinfectant to act on the test organism (*B. typhosus*), and the germicidal value is not determined upon the naked organism in broth culture, but an emulsion is made containing 3 per cent. of human fæces, dried at 102° C., and subsequently sterilized by steam at 120° C., to which the test organism is added. The results obtained by the Martin-Chick test indicate "phenol coefficients," which are very much less than those obtained by the "drop" method of Rideal and Walker. From this it would appear that the germicidal properties of many disinfectants of the coal tar series are very much reduced when the test organism is surrounded or protected by organic matter of the nature of human fæces.

A modification of the Rideal-Walker "drop" method has been suggested (the *Lancet*, November 20, 1909), in which *B. coli communis* is advocated as the test organism, instead of *B. typhosus*.

Disinfection may be carried out in several ways:—

1. By burning or exposure to high temperatures (hot air, steam, boiling).

2. By the action of oxidizing agents (atmospheric air, ozone, nitric peroxide, peroxide of hydrogen, chlorine, chlorates, bleaching powder, etc.). Oxygen burns up all organic matter into carbonic acid, ammonia, and water; but it exercises no selective influence on bacteria. Certain organisms die at once in atmospheres containing oxygen; some cannot exist in the absence of oxygen; while others are indifferent either to its presence or absence.

Fresh air is universally regarded as a powerful, if slow, disinfectant. Its powers in this respect are mainly due to the molecular oxygen contained in it; if, however, oxygen can be liberated in a nascent atomic condition, its activity considerably exceeds that of atmospheric oxygen. The disinfectant properties of fresh air are enhanced by the actinic rays of sunlight. Rays of sunlight, in the presence of air and moisture, will destroy even resistant organisms after varying periods of exposure; but there is no evidence of the destruction of the spores of anthrax bacilli by this means. The actinic rays probably exert their effects by promoting oxidation, or possibly by leading to the production

of small quantities of ozone and peroxide of hydrogen—two powerful oxidizers. The ultra-violet rays are much more powerful in this respect than the infra-red.

3. By the action of reducing agents (sulphurous acid, ferrous sulphate, etc.).

4. By agents which enter into combination with albumin (perchloride of mercury, sulphate of copper, etc.). These kill by their action on the albumin of the organism; or, by precipitating the albuminous matter around the germ, they may rob it of its nourishment.

5. By agents which exercise a direct poisonous effect on micro-organisms (perchloride of mercury, iodide of mercury, phenols, etc.).

Deodorants act by absorbing (slaked lime), condensing (charcoal), or oxidizing (permanganate of potash) odorous gases or vapours, such as sulphuretted hydrogen, ammonia, the compound ammonias, and some organic vapours. Many deodorants (charcoal, permanganate of potash, etc.) possess but little disinfecting power.

Having regard to the circumstances of actual practice, it must be borne in mind that no disinfectant can be expected to act instantaneously, for it cannot be brought to bear in sufficient volume upon all the organisms present; hence the agent should possess some degree of permanence in its action. Those disinfectants, for instance, which, by giving up oxygen, soon expend themselves in contact with organic matter, are inferior to substances like carbolic acid, which have greater permanence of action, and exert a direct toxic effect upon organisms. In practice, no agent of the kind which does not perform its functions within a limit of about thirty minutes can be regarded as satisfactory. Preference should be given to one which is non-poisonous to the higher forms of animal life, cheap, readily soluble in water, and otherwise convenient in use. It should not injure utensils in which it is placed, or articles exposed to its action, nor should it possess an offensive odour.

Burning.—This, the most efficient means of disinfection, can be applied often in the sick-room itself to all articles of little or no value. Rags used for receiving the discharges from the mouth and nose, or from the open wounds of patients in an infectious state, should be promptly placed upon the fire, before they have time to become dry. Old mattresses, pillows, and other large articles which are not required for further use should

be saturated with paraffin and burned. This is generally done in the small destructor which forms part of a disinfecting station. The stools of cholera and enteric fever patients may be cremated; if no destructor be available for the purpose, they must be mixed with plenty of sawdust, and the mixture then saturated with paraffin and ignited.

Boiling.—Infectious material which can be boiled for twenty minutes is thereby as a rule efficiently disinfected; but there is evidence that some of the more resistant organisms (*B. anthracis*) may resist boiling for longer periods. This method is most frequently employed for the purpose of disinfecting bed and body linen. It is important to bear in mind that if the articles are stained with albuminous matter, such as blood or fæces, the boiling tends to fix the stains; on this account the stains should first be removed by soaking in cold water, and, if necessary, by rubbing with a little soap.

Fæces have been disinfected in caldrons by means of steam, or by boiling with strong solutions of Izal, etc

Hot Air.—This method of disinfecting textile articles is rapidly falling into disuse; for the high temperature required to destroy resistant organisms injures the articles exposed, and an inconveniently long period of exposure is necessary to secure sufficient penetration of the heat into the interior of bulky objects. Dry air being a bad conductor, the heat penetrates slowly and imperfectly. Resistant bacteria placed in the interior of mattresses may survive an exposure of some three hours, even when the temperature to which the surfaces of the mattresses are exposed reaches 140° C.; but a temperature exceeding 120° C. would certainly damage many articles, such as wool, leather, and silk. By this method, therefore, fabrics are often damaged by scorching; but, short of this, they are liable to suffer a change in colour, to shrink, and to lose elasticity and gloss. Stains, especially those of an albuminous nature (blood, fæces), are liable to become fixed; but these can always be removed prior to disinfection by soaking and subsequent rubbing in cold water. Fusible substances, such as glue and wax, are melted, and the overdrying renders many articles brittle.

Dry heat is serviceable for articles of leather, morocco, and india-rubber, and for furs, books, and some other objects which are injured by the employment of the more efficient method next to be described.

Steam.—Steam under pressure penetrates into bulky and badly conducting articles, such as mattresses, pillows, and clothing, far more rapidly than dry heat. As such steam penetrates into the interstices of a cold body, it undergoes condensation, and imparts its latent heat instantaneously to the cold objects in contact with it. When thus condensed into water, it occupies only a very mall fraction (about $\frac{1}{1600}$) of its former volume. To fill the vacuum thus formed, more steam presses forward, in its turn yielding up its latent heat and becoming condensed, and so on until the whole mass has been penetrated. On the other hand, hot air in yielding up its heat undergoes contraction in volume only to a very small extent as compared with that undergone by steam in condensing to water.

Body-lice and their eggs are destroyed by exposure to steam at 100° C. for ten minutes, or to boiling water for five minutes.

The various stoves now employed for disinfecting by steam may be classified as follows:

1. Stoves in which steam without pressure is employed. These are of course cheaper, but, as the temperature of the steam does not exceed 100° C., less efficient than—

2. Those in which steam at low pressure (up to 5 pounds per square inch) is used. Although the temperature of nearly 110° C., which can be reached by these stoves, is sufficient for most purposes, a higher temperature can never be employed in them. These stoves, though cheaper, are therefore less efficient than—

3. Those in which steam at high pressure (10 pounds and over) can be employed. A temperature of 115° to 120° C.—which should not be exceeded—can be obtained in these stoves; and an exposure of articles for from a quarter to half an hour will suffice for their disinfection. The higher the pressure of the steam, the more rapid the penetration, and the less time required for disinfection.

The steam, which must be free from air, may be *current* or *confined*. Current steam serves to drive the air out of the interstices of fabrics, and thus to aid penetration; but since more steam is used, more fuel is consumed. In the stoves using steam confined under pressure, the steam should be allowed to escape from time to time, as this serves to displace the air (otherwise often compressed) in the centre of bulky articles. The greatest effect is of course produced when the steam has been under very high pressure.

The steam employed may be *saturated* or *superheated*, the former being far preferable to the latter, owing to its more rapid and thorough penetration. The use of superheated steam, therefore, involves a longer exposure in the chamber, and a greater expenditure of fuel, in addition to an increased liability to injure articles. The distinction between saturated and superheated steam is an important one. By increasing the pressure, steam may be generated at temperatures exceeding 100° C., but it always remains saturated steam; if, however, the steam is further raised in temperature without increasing the pressure, as may be done by bringing it into contact with a surface raised above its own temperature, it becomes *superheated*. Now, superheated steam has properties similar to those of a gas, and will not condense until it has parted with all its "superheat" by the slow process of conduction; whereas saturated steam, being a vapour, condenses at once on objects which are but slightly cooler than itself, and shrinks to about $\frac{1}{1600}$ of its former volume. It is this sudden and great shrinkage that leads to rapid penetration. Since penetration depends upon condensation, the disinfectant value of superheated steam does not much exceed that of dry air. The amount of "superheat" which is generally given to the steam in practice is not, however, sufficient to cause it to act very differently from saturated steam.

Steam, therefore, should not be superheated, or only to such a slight extent that it can at once condense upon any object slightly cooler than itself.

The time required for disinfection by steam obviously depends on the organism to be destroyed, the bulk of the infected articles, and the pressure of the steam employed. The best researches indicate a temperature of 115° to 120° C. for twenty minutes as alone trustworthy in all cases.

Satisfactory provision must be made to ensure that the infected articles are not allowed to become too wet, as otherwise colours are liable to run; and the disinfected articles should be fairly dry on removal.

By bearing the foregoing facts in mind, an opinion upon the suitability and efficiency of any steam disinfector can be readily formed. The rapidity of the penetration of heat into articles is ascertained by placing within them a thermometer, which, when the required temperature is reached, causes a bell to ring by

reason of the mercury completing the circuit of an electric current from a battery. The efficiency of the provision for drying the articles is gauged by the amount of moisture remaining in them after removal from the stove, as calculated by the increase in weight of the article. The maximum temperature reached in the stove and the uniform distribution of the heat may be tested by means of recently standardized maximum thermometers wrapped up in blankets and exposed in the stove; and the pressure within the stove can be ascertained at any time by the external pressure gauge.

The construction of the apparatus must be such as to combine simplicity of design with facility of management, so that highly skilled labour is not an absolute essential.

The *Nottingham* stove, made by Goddard, Massey, and Warner, consists of a rectangular chamber with a double wall or jacket, the lower part of the jacket containing water and serving as the boiler. Steam is made to occupy the space between the double wall, at a pressure of some 20 pounds; this serves to heat the walls of the chamber, and to a less extent the articles inside it, so that when the steam, also at a pressure of about 20 pounds, is allowed to fill the chamber, the condensation which would otherwise take place upon the walls of the chamber is prevented, and only a slight initial condensation on the surface of the now heated infected articles results. Articles are thus kept comparatively dry; but before they are removed they are further dried, either by allowing the steam to remain in the jacket, after that in the interior of the chamber has been removed, or preferably by drawing off the steam from the chamber and then drying by means of a current of hot air. The hot air (heated by steam, so as to limit the temperature and guard against scorching) can be drawn into the chamber by means of a vacuum apparatus. Steam exhausts are employed in some apparatus to produce a partial vacuum in the chamber prior to the admission of the steam, and these greatly promote, by the withdrawal of air, the rapidity of penetration.

The stove (*Washington-Lyon*) made by Manlove, Alliott and Co., is oval in section, and the steam is led into the jacket and the chamber of the stove from a special detached boiler. The disinfector is fitted with a vacuum apparatus and hot-air chamber. In working, steam is first admitted into the jacket; then a vacuum is created in the oven, so as to withdraw air. Steam is then

admitted into the oven, and a pressure equivalent to a temperature of 115° or 120° C. maintained for twenty minutes. A vacuum is again produced, and finally air heated by passing over the steam coils in the hot-air chamber is admitted, so as to dry the steam-heated articles. The whole process occupies rather over thirty minutes from the time the infected articles are introduced into the oven. There is an advantage in having a separate detached boiler, which can be readily inspected and tested for boiler insurance purposes.

The *Velox* high-pressure steam disinfector is made in several sizes, and can be adapted to work at any desired pressure up to 15 pounds. An internal coil is provided through which the steam is passed for heating purposes prior to the actual disinfection, and also to dry the articles afterwards.

Thresh's Stove.—Here current steam is employed, without pressure, at a temperature of about 105° C., the "superheat" being obtained by using in the boiler a calcium chloride solution, the boiling-point of which is considerably above that of water. The lower part of the jacket of the cylinder, which contains the saline solution, acts as the boiler, and is heated by a small furnace. The steam, which enters the chamber, escapes continuously through a chimney. For the subsequent displacement of the steam and for the drying of the articles, hot air is drawn into the chamber through a coil of tubes, which is surrounded and heated by the boiling solution.

A current saturated pressure steam disinfector (Delépine-Jones) is also supplied by the Thresh Disinfector Company.

Steam disinfectors are made portable, so that they may be taken to infected premises, or be moved from village to village. Their cost varies from about 60 to 150 guineas, according to the size.

In all those apparatus in which steam is employed at a low pressure or in a superheated form (*i.e.*, at temperatures not exceeding 104° to 110° C.), most objects should be exposed for at least one hour.

The Sack Steam Disinfector (Messrs. Meldrums) is a simple, easily worked, and economical device for the disinfection and "disinfestation" of clothing and bedding, etc. A sack, of material rendered steam proof, receives the textile articles, and the steam enters at the top of the sack, the displaced air being given an escape at the bottom of the sack. Most articles are disinfected

in fifteen minutes, and on removal from the sack they become quite dry within two or three minutes. The method is quite efficient for the disinfection of non-sporing organisms, and seeing that the whole apparatus is easily portable upon a cycle, it should prove very useful in country districts, as well as for schools and other institutions.

Formic aldehyde vapour mixed with current steam under reduced pressure (by aspiration), and therefore at a reduced temperature (70° to 80° C.), proves satisfactory for the disinfection

Fig. 88.—The Sack Steam Disinfector.
The complete apparatus ready for work in a small shed, showing small oil lamp and boiler.

of articles likely to be injured by the employment of high temperature steam, such as books and leathern articles (*vide* p. 706).

A *disinfecting station* should comprise:

1. Two rooms completely separated from each other by a wall, into which the stove is built, so that it communicates with both rooms. The infected articles are brought into one room and placed in the stove, and after disinfection they are removed from the other end of the stove, which opens into the non-infected room. No infectious material must be allowed to enter the non-infected room, and there should be no direct means of

communication between it and the infected room. The workers in the infected side should always wear "overalls." The floors and walls of both rooms should be made of some smooth and non-porous material, which can be readily and efficiently cleansed by water; and exceptionally good provision should be made for ventilation and light.

2. An incinerator or destructor, provided with a small second fire to cremate the products of imperfect combustion before they pass up the flue.

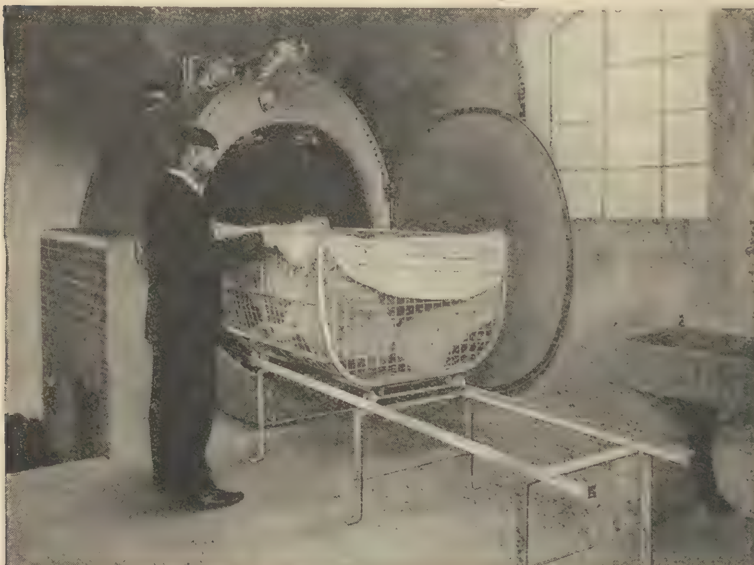


FIG. 89.—FURNACE-HEATED DOUBLE-DOOR DISINFECTOR, SHOWING BRICKWORK SETTING, ETC.

3. Separate sheds must be provided for (*a*) vans employed to bring in infected articles, and (*b*) those employed to return the disinfected articles.

4. A laundry and bath-room sometimes form part of a disinfecting station, a charge being made for any laundry work undertaken.

DISINFECTANTS EMPLOYED IN LIQUID FORM.

Solutions of the following substances are employed:

Perchloride of Mercury ($HgCl_2$, corrosive sublimate).—This is one of the most powerful and one of the most convenient dis-

infectant agents known. It forms a colourless, non-odorous solution, which is, however, poisonous to human beings. Unless the solution is acidulated, it has a marked precipitating effect upon albumin, and its power of penetration into the interior of particles of organic matter is thereby limited.

It acts as a direct poison to bacteria, and also exerts its disinfectant action by coagulating their protoplasm.

One part of the salt to 1,000 parts of water constitutes a stronger disinfectant than even 5 per cent. carbolic solution, and it is trustworthy for the disinfection of non-spore-bearing bacteria; but 1 in 500 is necessary for spore-bearing bacteria.

The solution should not be stored in metal receptacles, as it corrodes them, and is then liable to decomposition. It should always be made distinctly acid, and a little colouring matter should be added to guard against its being swallowed in mistake for water. For the same reason it should be placed in dark blue bottles bearing a large poison label.

Half an ounce of perchloride of mercury, 1 ounce of hydrochloric acid, and 1 grain of aniline blue, to 3 gallons of water, is a mixture which costs about fourpence, and furnishes a non-staining disinfectant solution, containing about 1 in 1,000 of the perchloride.

The salt has been made up into tablets of about 20 grains each in weight, so that one tablet to a quart of water furnishes a solution of 1 in 1,000 of the perchloride. This constitutes a portable form, convenient to travellers and troops on the march; but there is risk in introducing the tablets, which look very like sweets, into ordinary households.

Mercuric Iodide (HgI_2) is less poisonous than the perchloride, and does not precipitate albumin to the same extent. Its disinfectant power is at least equal to, and there is evidence that it even excels, that of the perchloride. It constitutes an excellent disinfectant solution for the hands. Although insoluble in pure water, it is readily soluble in the presence of excess of iodide of potassium. Like the perchloride, it attacks metals.

Phenols are obtained from tar distillates as dark oily liquids, which contain in the crude state, besides the many members of the phenol group, the neutral tar oils. Phenols are poisonous, possess a caustic action, and coagulate albumin.

Carbolic Acid (C_6H_6O) is the member of the group most employed for disinfecting purposes, although its powers are slightly

inferior to those of cresylic acid (C_7H_8O). It is not a true deodorant, but it masks offensive gases and vapours by its own strong and unpleasant odour. A 5 per cent. solution at least must be employed against resistant organisms. Many trade products, consisting of oils procured from the destructive distillation of coal, are on the market, and they for the most part possess disinfectant value similar to that of carbolic acid. They are mostly dark brown liquids which, when added to water, form milky emulsions, one advantage in their use being that they are practically non-poisonous, and somewhat cheaper than pure carbolic acid. *Izal*, containing a body allied to the phenols of the carbolic acid series, is a powerful and valuable disinfectant; it is practically non-poisonous. It mixes well with water and has an agreeable odour. According to Klein, an emulsion of 1 in 200 disinfects non-spore-bearing organisms in 5 minutes, and a 10 per cent. solution kills even the virulent spores of *B. anthracis* in about 15 minutes. *Cyllin* is very similar to *Izal* in its disinfectant property. *Saprol* is a dark brown oily fluid, much used in Germany; it appears to be of similar strength to carbolic acid, and possesses the advantage that, while its contained phenols mix with a liquid, an oily film floats over its surface.

The disinfectants, like izal, cyllin, lysol, sanitas-okol, sanitas-bactox, kerol, MacDougal's M.O.H. fluid, Lawes' fluid, Cooke's cofectant fluid, Jeyes' fluid, etc., which are coal tar derivatives, contain varying proportions of phenols, neutral oils, resins and fatty acids, and water. Most of them are able to form emulsions with water by reason of the presence of the resins and fatty acids; but in some a non-resinous emulsifier, such as gelatine, is used. It seems probable that the activity of these disinfectants is in part dependent on the fineness of the emulsification formed when the crude article is mixed with water. The fine particles of an emulsion are in a constant state of Brownian movement, and thus a kind of bombardment of the micro-organisms is kept up by these incessant movements of the disinfectant molecules. In the presence of organic matter, however, whether in solution or in suspension, the Brownian movements of the particles of the emulsion appear to be impeded, with the result that the germicidal action of the emulsified disinfectant is not nearly so great as when it has to act only on the naked organism. Where the organisms to be destroyed are in the presence of an excess of

organic matter, it is possible that emulsions may have but little advantage over clear solutions.

Chloride of Lime, $Ca(ClO)_2$, bleaching powder, is a mixture of chloride and hypochlorite of calcium, and should contain about 33 per cent. of available chlorine. It gives off a most unpleasant odour. Chloride of lime solution is made by first stirring up the bleaching powder with a little water so as to make a thick cream, and then diluting to the required extent. The solution exerts a corrosive action on metals; it tends to dissolve the albumin of fæcal and other matter, and its powers may be entirely exhausted upon such organic matter, bacteria consequently escaping. The disinfectant and deodorizing action of the solution is due to the fact that, in presence of moisture and carbonic or other acids, hypochlorous acid ($HClO$) is liberated, and this acts as an oxidizing agent by splitting up into HCl and O. A 1·5 per cent. solution of the powder (about 2¼ ounces to the gallon), containing 0·5 per cent. of available chlorine, should generally be employed, except when dealing with organisms whose resistance is known to be slight; in such cases experiments show that a solution containing 1 part of chlorine in 1,000 will suffice.

Sodium Hypochlorite, like bleaching powder, possesses considerable disinfecting power on account of its available chlorine. The strength at which it should be employed must be governed by the fact that the solution should contain in practice at least 0·5 per cent. of available chlorine, except where organisms of little resistance are to be dealt with. A liquid on the market, sold as *Chloros*, contains 10 per cent. of available chlorine. Solutions of hypochlorites are apt to lose their strength somewhat on keeping; they should therefore be kept tightly stoppered in a dark place. The absence of lime renders a solution of sodium hypochlorite preferable to one of bleaching powder, when the disinfectant is to be emptied down the drains.

Chloramine-T.—Dr. Dakin has shown that the antiseptic action of hypochlorites depends not upon their oxidizing properties, as had been commonly supposed, but on the formation of chloramines (bodies containing the NCl linking) from proteins. One of these substances is Chloramine-T (*toluene sodium sulphochloramide*). It is of great value for general antiseptic purposes, being non-toxic. It has also been recently used as a means of treatment of carriers of the meningococcus (the organism of

cerebro-spinal fever). An *inhalatorium* has been constructed, in which an automatic steam spray is used for charging the air with disinfectant. By use of a 2 per cent. solution of Chloramine-T the air of the room is rendered strongly bactericidal to many bacteria, but can be tolerated by human beings for periods up to twenty minutes without harm. Carriers, in whose nasal passages the meningococcus was found in large numbers, were found to be freed from that potential danger to themselves and others after inhaling the air so treated. Such a method may in the future become available for preventive treatment in regard to diphtheria, poliomyelitis, influenza, and other infectious diseases, and play an important part in the routine sanitation of the upper respiratory passages.

Hypochlorous Acid is formed by the electrolysis of sea-water (Hermite process), which is thereby constituted a powerful deodorizing, but weak and unstable, disinfectant solution. The electrolysis of a solution of magnesium and sodium chlorides produces a mixture containing available chlorine in a more stable condition than is the case with electrolyzed sea-water.

Electrolyzed sea-water has been found extremely useful for maintaining hospital ships, with a full complement of sick and wounded, in good sanitary condition during voyages. The electrolyzed sea-water is applied to the floors and walls of the wards, and in the latrines and bedpans. Cases of secondary infections of wounds were almost abolished by its use, and no damage is done to any of the ship's structures, when the solution is suitably diluted. With a suitable plant, the fluid can be manufactured at a cost of about 3d. per 100 gallons.

Hydrochloric and other mineral acids are markedly disinfectant when employed in such strengths as will give the solution a marked acid reaction.

Sulphate of Copper ($CuSO_4$).—In 5 per cent. solution this salt is a powerful disinfectant. It acts by coagulating albumin and by exerting a poisonous action on bacteria. It will absorb ammonia, the compound ammonias, sulphuretted hydrogen, etc., and is therefore a useful deodorant.

Chloride of Zinc ($ZnCl_2$) is a poisonous salt with very similar properties to those of sulphate of copper. A 10 per cent. solution, to which a little hydrochloric acid has been added, should be employed where spores are concerned, but 5 per cent. will suffice for non-spore-bearing bacteria; it has, however, a corrosive

action if used in solutions containing much more than 5 per cent. of the salt. Its disinfectant powers are somewhat inferior to those of sulphate of copper, but they are far superior to those of ferrous sulphate. "Burnett's Fluid" contains about 50 per cent. of $ZnCl_2$.

Ferrous Sulphate ($FeSO_4 7H_2O$, Green Copperas) acts mainly by its reducing action while taking up oxygen to become a ferric salt. It is a feeble disinfectant unless used in great strength (20 to 30 per cent.), but it is a good deodorant, absorbing ammonia and sulphuretted hydrogen. In practice it is suitable only for excreta, as it stains badly, and tends to form iron moulds. The same general remarks apply to Fe_2Cl_6 (Ferric Chloride), which is, however, a feeble oxidizer.

Potassium Permanganate ($K_2Mn_2O_8$) is an oxidizing agent which can only be used in practice in weak solutions as a deodorant, since a 5 per cent. solution, at least, is required for the disinfection of resistant organisms. A solution of this strength would be expensive, and would stain everything with which it came in contact. Gases, like sulphuretted hydrogen, reducing salts in solution, and the more unstable organic matter, first rob the permanganate of its oxygen; and the whole of the permanganic radical may be reduced to black manganic oxide, or even to a lower oxide, before the bacteria are destroyed.

"*Condy's Red Fluid*" is a mixture of the permanganate and sulphate of soda.

Formic Aldehyde (CHOH), in solution of 1 to 2 per cent., is a rapid disinfectant and deodorant; it costs far less than carbolic acid of equal disinfecting strength. An aldehyde is an alcohol *dehydrogenated;* thus, wood spirit (methyl alcohol, CH_3OH), when deprived of H_2, becomes CHOH, called formic aldehyde because it very readily changes to formic acid (CHOOH). In aqueous solution the gas can be concentrated to about 40 per cent., in which state it is sold as "Formalin."

Sanitas Fluid has the odour of pine wood, and is a practically non-poisonous liquid. Used in the strength of 10 per cent. in water, it is said to be capable of destroying non-spore-bearing organisms in 10 minutes. It is one of the less powerful disinfectants.

Disinfectants employed in Gaseous Form.

Formic Aldehyde is also used as a gaseous disinfectant. The aldehyde vapours, which are non-poisonous, but very irritating to the eyes and throat, are powerfully disinfectant and deodorant. So far as their application for the purpose of the *surface* disinfection of rooms is concerned, they may be regarded as likely to fulfil all the requirements of general practice, if they are employed in sufficient quantities. Formic aldehyde is more rapidly disinfectant than equal quantities of sulphurous acid, and it does not affect colours or (with the exception of iron or steel) metallic surfaces, although it fixes stains of blood or fæces. It is somewhat difficult to confine to the room, but there is no danger and little difficulty attending its practical application if the rooms are well sealed up.

Formalin vapour is most efficacious at a temperature of 70° F. and a humidity of 70 per cent.; if temperature and humidity are much below these optimum conditions, the disinfection can hardly be regarded as reliable.

The production of the gas by means of specially devised methyl-alcohol lamps is often imperfect and unsatisfactory in practice. In these the aldehyde is generated by allowing the vapour of wood alcohol, well mixed with air, to pass over the surface of red-hot platinum, when the alcohol is converted into aldehyde and water. The gas can best be liberated from formalin by means of Trillat's apparatus, in which the formalin is heated under pressure in an autoclave. A little calcium chloride is placed in the solution, which is then known as "formo-chlorol," and as the boiling point of the calcium chloride solution is above 100° C., and the aldehyde is given off below that temperature, it may in this manner be obtained in a practically dry state. When the attached pressure gauge registers a pressure of 40 pounds in the autoclave, the vapours are allowed to escape through a long tin copper tube, which is passed through the keyhole into the infected compartment. Half an hour is required to get up the necessary pressure, and in an ordinary sized room the vapours would be allowed to escape for about half an hour. From $\frac{1}{2}$ to 1 litre of formo-chlorol should be employed for every 1,000 cubic feet, an extra quantity of the liquid being used in the autoclave to guard against danger from

drying up. About twenty minutes is required to rid each litre of formo-chlorol of its aldehyde.

This constitutes the best known means of liberating large quantities of the aldehyde. Owing to the large quantities which can be generated and the high diffusibility of the gas, the method is specially suitable where passages, corridors, or staircases, with communicating rooms, require disinfection at the same time. The drawbacks against the adoption of the method by sanitary authorities are the weight of the apparatus and the time consumed in getting up steam and charging the room.

If an attempt is made to concentrate aqueous solutions of the aldehyde beyond 40 per cent. polymerization ensues, and a white precipitate of paraformaldehyde forms. This material is made into small tablets and sold as "Paraform Tablets," each weighing about one gramme. A considerable amount of the aldehyde may be obtained, in a very convenient manner, by means of a spirit lamp so constructed that the hot and moist products of combustion from the lamp act upon these paraform tablets. Twenty-five tablets should be employed to every 1,000 cubic feet of space.

Lingner's glyco-formal vaporizing apparatus has furnished better results in the hands of experimenters than those obtained from the use of paraform tablets. The apparatus consists of a ring boiler in which steam is generated and driven into a reservoir containing a mixture of formic aldehyde, glycerine, and water, which is thus vaporized and injected in fine sprays into the room.

The gas is neutralized by ammonia; and, if necessary, the last traces can be removed from a room by exposing vessels containing a little dilute solution of ammonia. Goggles, specially made so as to protect the eyes, may be worn when the room is unsealed.

The Autan method of producing formaldehyde is as follows: For every 1,000 cubic feet of room space to be disinfected take 5 ounces of potassium permanganate crystals, and place in a metallic pail. Take ½ pint of formalin (37 to 40 per cent. formic aldehyde) and pour over the permanganate crystals. After a few seconds chemical action takes place between the permanganate and about one-fifth of the formaldehyde, which produces heat sufficient to evaporate nearly all the remainder. The room must be closed and sealed in the ordinary way, and kept closed for six hours. Where formalin is not available, 100 para-

form tablets (1 gramme each) may be taken, crushed into a powder, placed in a pint of hot water, which is rapidly brought to boiling point, and used as if it were liquid formalin. Double the amount of potassium permanganate should be used—namely, 10 ounces, instead of 5 ounces, per 1,000 cubic feet. In all cases the amount of the permanganate needed is exactly half the weight of the liquid to be added. As the mixture is liable to froth over and escape from the container, and thus lead to the injury of carpets, it is necessary to use a large and deep container.

Sulphurous Acid (SO_2) is a gas with a density about double that of the atmosphere, and which therefore diffuses badly. It has a slight bleaching action, which is not sufficient, however, to militate against its use. In association with moisture it has marked disinfectant powers, a 5 per cent. solution killing the spores of *B. anthracis*, and a 1 per cent. solution killing non-spore-bearing bacteria, within twenty-four hours, according to Koch; but used in the gaseous form it is little more than antiseptic. Like other acids, sulphurous acid absorbs ammonia, compound ammonias, and organic bases (ptomaines, etc.); it decomposes sulphides and sulphuretted hydrogen, and reduces or enters into combination with organic matter; it also probably exerts a direct toxic effect on bacteria.

The old process of disinfecting a room by sulphurous acid is rapidly going out of use, now that equally convenient and more efficient methods are available. The former very general practice admitted of division into two stages:

1. The charging of the atmosphere for from six to twenty-four hours with from 1 to 2 per cent. of the gas.

2. A subsequent thorough aeration of the room for several hours—an essential feature of this method.

The gas was generated and employed as follows:

1. Rolled sulphur was broken up into pieces of about the size of a marble, placed in an iron vessel, and then moistened with a little spirit and ignited. At least 2 pounds of sulphur was advocated for every 1,000 cubic feet of space, about 2 per cent. of sulphurous acid being thereby furnished to the atmosphere. The fact that the sulphur did not always burn out was a drawback to this method, and it was therefore found preferable to employ—

2. Sulphur candles, in which the powdered sulphur, mixed

with inflammable material, was placed in a small metal saucer and lighted by a wick. These invariably burn out, and were very convenient and expeditious in use.

3. An ordinary benzoline lamp filled with carbon bisulphide; as this burns, sulphurous acid is given off ($CS_2 + 2O_2 = CO_2 + SO_2 + S$).

4. The gas can be liquefied by a pressure of three atmospheres (about 45 pounds to the square inch), the liquefied gas being passed into metal cylinders holding about 20 ounces. In use, a short piece of lead pipe with soldered end, which communicates with the interior, is cut off, and the cylinder placed in a basin with the cut surface downwards, when the liquid, being relieved of its pressure, passes into the gaseous state. At least two cylinders were recommended to every 1,000 cubic feet of space, for the contents of one cylinder would furnish slightly under 1 per cent. There is experimental evidence that the gas liberated from the liquid state is not so efficient as that obtained directly from the burning of sulphur.

Accidents by fire, when burning sulphur was used, have been very rare, but to guard against them it is well to support the burning sulphur over a pail or basin of water. This water, especially if hot, aids in saturating the atmosphere, and thereby increasing the disinfecting power of the gas.

A sufficiency of moisture must be present in the air of the room if the SO_2 generated is to exert disinfectant properties. If the pan containing the sulphur to be burnt is placed in a shallow dish containing water, owing to the amount of heat evolved in the burning, aqueous vapour is formed from the water in sufficient amount to saturate the atmosphere, and good results may be obtained. The saturation of the atmosphere may be assumed if, on the opening of the room after twelve or twenty-four hours, condensed moisture is found on the floor, walls, and surfaces of the apartment. The heat of the combustion of the sulphur causes the gas to expand, and materially aids in its diffusion. The gas should be evolved as high as possible in the room, and at more than one place unless the room is very small, so as to aid diffusion and prevent oxidation of the gas before diffusion takes place. Colonel Beveridge, R.A.M.C., who has made experiments on sulphur fumigation, recommends that 3 pounds of sulphur should be burned for every 1,000 cubic feet of space. This amount of sulphur, which theoretically produces 3·5 per cent. of SO_2 in the air, was found

46

in all cases to be effective in destroying cultures of different organisms exposed at the level of the floor or ceiling after twenty-four hours' exposure. Colonel Beveridge estimates that five cylinders of compressed SO_2 (liquefied), each containing 20 ounces, would be required to produce a percentage of SO_2 equal to that evolved by burning 3 pounds of sulphur. The gas liberated in this manner from tins of liquefied gas does not diffuse nearly so well as the gas given off by burning sulphur, and unless the air of the room is previously moistened by steam or other means, the requisite amount of aqueous vapour is not present to enable the liberated gas to exert its disinfectant properties.

Sulphurous acid gas is very useful for the purpose of destroying vermin, and in this respect it is far more powerful than formic aldehyde.

The gas is so irrespirable that it is often impossible to enter and unseal the room containing it. A wet towel, moistened with washing soda, and placed over the mouth, will always enable the operator to enter. As bronze, gilt, and copper surfaces are tarnished by the sulphur fumes, these should, where detachable, be wiped with 1 per cent. carbolic and placed just outside the room prior to the liberation of the sulphurous acid.

Chlorine (Cl).—This gas has most of the defects of sulphurous acid; it is a very irritant and heavy gas, which diffuses badly, and moisture is essential to its disinfectant action. Compared with sulphurous acid, it is a heavier gas, possessing greater bleaching properties, and somewhat more irritant; it is less convenient in use and more expensive. On the other hand, when present to the extent of 1 per cent. in the atmosphere, its disinfectant power considerably exceeds that of a similar strength of sulphurous acid.

The disinfectant and deodorant properties of the gas depend upon its affinity for hydrogen. Thus, in the presence of moisture, and especially in daylight, it releases nascent oxygen ($Cl_2 + H_2O = 2HCl + O$), which burns up organic matter, including bacteria. It decomposes sulphuretted hydrogen

$$(Cl_2 + SH_2 = 2HCl + S),$$

and also ammonia

$$(3Cl_2 + 8NH_3 = 6NH_4Cl + N_2).$$

It is usually produced by the action of sulphuric or hydrochloric acid on bleaching powder—

$$Ca(ClO)_2 + 4HCl = 2Cl_2 + CaCl_2 + 2H_2O.$$

It is advisable to use 2 pounds of bleaching powder and about 1 pound of the commercial acid for every 1,000 cubic feet of space. The mixture should be divided into several parts, because of its bulk and to ensure distribution of the gas, and placed as high in the room as practicable. Some experiments indicate the necessity of using much larger quantities of the bleaching powder for the more resistant infections. The powder contains about 35 per cent. of available chlorine, and it must be kept dry.

All metal fittings and articles of silk, etc., should be removed beforehand; and if great difficulty is experienced in entering the room for the purpose of unsealing, the operator should first saturate a towel with weak ammonia solution and place it over his mouth.

Good results have been obtained by the employment of "*Bacterol*" vapour in a sealed room or special cabinet.

Vaporized Phenol (C_6H_6O).—Although it is claimed by some that the use of this agent succeeds well in practice, such large quantities have to be employed that the odour which remains after use is extremely persistent. The phenol, placed in a bottle-shaped metal receiver, may be vaporized by means of an iron rod made red hot, which is placed inside the receiver and allowed to remain there. A pint of phenol can be vaporized in this way.

Disinfectants employed in Solid Form.

These can only be conveniently and effectually employed as deodorants in the form of powders.

Powders are made containing phenols, sulphurous acid, etc., but they all lose strength on keeping.

Carbolic Powders.—The "vehicle" for the carbolic acid is frequently lime, which is often in very great excess. There is a resulting formation of carbolate of lime, and the powder soon becomes practically inert, for the reason that it contains little or no available carbolic acid. The best class of carbolic powders are warranted to contain at least 15 per cent. of phenols, silicious matter, not lime, being used as their basis ("carbolized silicate powders"), or absorbent wood fibre, or peat ("carbolized peat

powders"). All such powders are liable to lose from 1 to 2 per cent. of carbolic acid by volatilization.

Slaked Lime is a good deodorant, as it absorbs sulphuretted hydrogen and most organic vapours. Like *bleaching powder*, it exerts a caustic action, and attacks metals. Bleaching powder (chloride of lime) deposits about 40 per cent. of lime, and should not, therefore, be put down drains.

A mixture of equal parts of "Sanitas Powder" and lime is a good deodorant, which of itself gives off no unpleasant odour.

Ordinary *Soap* possesses marked disinfecting properties. There is little or no advantage in using soaps impregnated with small quantities of disinfectants.

Room Disinfection.

Wearing apparel and bedding should be steam disinfected; and if carpets, curtains, rugs, and upholstered articles were not removed when the sick-room was prepared for the patient, these should also be set aside for steam disinfection. Thus the disinfection of the room is practically one of surface disinfection only, for no gas or vapour, employed at the current temperature and pressure, possesses powers of penetration to any valuable degree.

To be satisfactory in practice, methods of room disinfection must be efficient but must not injure the articles exposed. The facility of application and the cost are also important considerations.

There are three well-known methods of disinfecting the exposed surfaces in rooms, involving:—

1. The use of sprays or atomizers, by which the disinfectant (in solution) can be applied directly in the form of a very fine spray to the surfaces of the room.

2. The washing of all surfaces with a solution of the disinfectant, or the rubbing down of such surfaces with bread-crumbs.

3. Fumigation, in which the air is charged with the disinfectant in the form of a gas or vapour, for a period of from six to twenty-four hours. In this method the room should be, as far as possible, hermetically sealed—the windows closed and chinks pasted over with paper, the chimney outlet closed up, and the door crevices and keyhole carefully pasted over. Before the room is again occupied, all the flat surfaces of the room upon

which dust can settle should be washed down with some disinfectant solution.

In the case of schools and hospitals, the skirting and floor boards should be removed and washed, and all ventilators should be swept out and disinfected.

4. It is advisable in most cases to strip the wall-papers and limewhite the ceiling as a further precaution.

After the room has been dealt with, the bedding, clothes, etc., should be placed within canvas bags, which should be damped outside with water, and then taken to the van for removal to the disinfecting station for steam disinfection. The moistening of the bag is a precaution against the dislodgment and escape of bacteria from it during the removal of the articles from the room, through the house, and to the station.

As mistakes sometimes happen, it is necessary to make out a list of articles removed from each house, and to obtain the signature of some responsible person to this list. The use of canvas bags, which can be placed with their contents direct into the stove, reduces the possibility of the mixing of articles from different houses, and obviates the necessity of the man at the station handling the infected articles. Any articles, however, which are stained, and require to have the stains removed before being placed in the stove, would be overlooked unless a special bundle is made of them; and books, leather articles, feathers, and furs, which are injured by steam disinfection, must be separately collected together.

The individual engaged in preparing a room for disinfection should always wear overalls, which should be afterwards left behind in the room, and removed with the other articles for steam disinfection. This precaution diminishes the risk of the infection being conveyed from the sick-room, and when the disinfection is performed by the sanitary authority the precaution serves as a useful object-lesson to the people.

A great deal has been claimed for the spray method of disinfection in France, where it is the official one.

The efficiency of a good sprayer must depend on its ability to deliver the liquid in the most finely divided state possible, for the more this requirement is met, the more uniform will be the distribution of the disinfectant. The Equifex sprayer consists of a metal reservoir, which holds the disinfectant, and is lined with ebonite, so that the metal is not attacked. The fluid is

driven through a spray nozzle by means of a hand pump, which forces air into the reservoir. An extremely fine spray, at a velocity sufficient to ensure a slight degree of penetration, is made to issue from the end of a metal tube of such length that it can be held close to all the surfaces to be treated.

The spraying process must be carried out in the most complete manner, inch by inch, over all the surfaces it is intended to disinfect. It is calculated that to efficiently disinfect 800 square feet of wall space two hours' spraying is required.

Lumley's "Invicta" spray requires no pumping when at work, the disinfecting solution in the tank of the apparatus being brought under an air pressure of 45 pounds to the square inch, which causes the spraying. This is a much cheaper form of spray producer than the "Equifex."

The disinfecting solutions to be preferred in spraying are: perchloride of mercury, formic aldehyde, "Chinosol," or sodium hypochlorite. The operation of disinfecting a small room occupies one hour.

Washing and rubbing methods appear to be efficient. All the horizontal surfaces of a room may be washed down, or coated with disinfectant by means of a large paint brush, and the vertical surfaces may be wiped and stroked with a rag moistened with the disinfectant. When a brush is employed, two coats of the disinfectant should be put on, one with vertical strokes and the other with horizontal, to ensure that the disinfectant reaches all the crevices. The German official method is to rub down the walls with bread—ordinary German loaves, forty-eight hours old, being employed, cut into pieces 6 inches square, with the crust at the back to afford a firm hold. The crumbs having been swept up and burned, the walls and ceiling are thoroughly sprinkled with carbolic solution, and the floors and furniture are washed with this solution.

An advantage which is claimed for gaseous disinfectants is that their use necessitates, before the room can be reoccupied, a thorough exposure to fresh air for several hours—itself a useful adjunct to disinfection.

While the room is occupied by an infectious patient, it is a very general custom to hang a sheet outside the door, and to keep this sheet constantly moistened with disinfectant. There is a tendency to regard the practice as useless, but its retention is certainly to be advocated. Although such a sheet cannot

present an impassable barrier to the passage of infection, it must tend to limit the infection; and its presence serves as a warning to all, and an object-lesson of the constant necessity for precaution.

The infectious sick-room should be kept clean by means of damp sweeping and dusting. It has been demonstrated that minute drops of infected moisture may be sprayed into the room by a patient coughing, sneezing, or even speaking; and that such drops may be scattered to a distance of 4 feet from the patient.

BOOKS.—Books, leathern articles, furs, and feathers liable to injury by being placed in a hot air stove may be disinfected in a small compartment in which formic aldehyde vapours, in sufficient quantity to furnish 3 per cent. to the atmosphere, are generated.

The compartment is then sealed for three or four hours. In the ceiling of the compartment several lines of wire are loosely fixed, so that the books can be suspended by their covers, the pages being open, fan-shape, to admit the disinfectant; or the articles may be placed upon perforated shelves arranged above the apparatus from which the formic aldehyde is being liberated. It does not appear that books harbour infection except when they are old and soiled.

DEAD BODIES should be wrapped in a sheet soaked in "Izal" (2 per cent.), carbolic acid (5 per cent.), perchloride of mercury (1 in 500), formic aldehyde (1 per cent.), or other disinfectants of equal strength. Cremation is specially desirable in the case of infectious bodies.

GULLEYS may be sprinkled over with a good carbolic powder, or with a mixture of equal parts of "Sanitas Powder" and lime. Bleaching powder has too unpleasant an odour, and it badly corrodes the metal grids.

STOOLS, ETC.—To disinfect enteric fever stools, cholera evacuations, tubercular sputa, and other discharges from the infectious sick, either liquid disinfectants, boiling, or cremation must be resorted to. The following liquid disinfectants may be employed: Acid solution of corrosive sublimate (1 in 500) coloured blue with aniline. Preparations containing carbolic or cresylic acid (10 per cent.), or four tablespoonfuls of the acids to 1 pint of water; solution of sulphate of copper or ferrous sulphate (10 per cent.); solution of formic aldehyde (4 per cent.); bleaching powder

solution acidified (4 per cent.). All solid stools should be broken up with a piece of stick and thoroughly mixed with the disinfectant. The agent must be allowed to remain in contact with the infected material for at least half an hour; and all disinfectant solutions must be added to the matter to be disinfected in such quantities that they are *present in the whole mixture* to the required extent, as indicated above. Even then, some of the excreta may escape disinfection. Sputum is disinfected with great difficulty by means of liquid disinfectants; and either burning or steam for 20 minutes should be employed in preference to other methods.

Enteric and cholera stools are preferably disinfected by the following means:—

Boiling for half an hour under steam pressure; boiling for half an hour with 1 in 20 carbolic acid solution; mixing with a relatively large amount of straw or sawdust, then saturating with paraffin or petroleum and burning; mixing with coal dust and ashes, and burning in an incinerator with a high flue. It has been found that the mixing of about a cupful of commercial unslaked lime to a typhoid stool will generate enough heat to kill the typhoid organism if a little hot water is employed.

The impossibility of disinfecting or sterilizing large volumes of sewage or night soil by the use of chemical reagents, unless applied in enormous and ruinous quantities, need hardly be insisted on. Small quantities of chemical reagents may be very efficient deodorizers, for offensive smells are thus concealed or destroyed; but the removal of offensiveness must never be regarded as equivalent to destruction of infection.

Hands.—The disinfection of the hands is a matter of great difficulty, and it is, therefore, wise to protect the hands, where possible, by wearing thin india-rubber gloves. The best practical means of dealing with infected hands is to scrub them thoroughly with soap and hot water, using a nail brush assiduously, then to scrub and soak them in absolute alcohol for five minutes, and then to steep them for five minutes in a solution containing 1 in 500 of the iodide of mercury dissolved in the iodide of potassium. It is useful to have a little alcohol added to the disinfectant solution.

Ships.—Clayton gas is a useful means of disinfecting ships. The Clayton apparatus consists of an iron furnace specially constructed to burn sulphur in a current of air, a flexible rubber

hose conveying the gas from the apparatus to any part of the ship. The gas contains about 15 per cent. of sulphurous acid, together with some sulphuric acid. It is usually recommended that one pound of sulphur is required for the disinfection of 250 cubic feet of space, so that there may be from 3 to 5 per cent. of the gas in the atmosphere of the compartment to be disinfected. There is testimony to the fact that all rats and insects in a ship are destroyed in two hours in these circumstances; but, although the method is valuable for cabins and empty holds, owing to the rapid absorption of sulphur di-oxide by most articles of cargo, its use on this account for laden vessels is restricted. Pathogenic bacteria require a somewhat larger percentage of the gas and an exposure of several hours; and sporing specific organisms (such as Anthrax) cannot be thus disinfected. Although the application of the process is subject to considerable limitations, it is better on the whole than either of the processes which have been suggested involving the use of carbonic acid or carbon monoxide; for, with these disinfectants, rats, etc., die in their hiding-places, whereas they more often come out into the open to die when exposed to sulphurous acid.

FLEAS AND BUGS.—The body-louse (*Pediculus vestimenti*) closely resembles the head-louse. It lives in the creases of the garments worn next the skin, and, after biting, sucks blood from the skin. The female deposits its ova on the garments it infects, and the embryos are hatched out in about a week. Both head and body lice are transferred from person to person by close contact or by the wearing of infected caps or clothes (*see* p. 293).

The common flea (*Pulex irritans*) takes nearly four weeks to develop from the egg. The female deposits its barrel-shaped white eggs in the cracks of furniture, walls, or floors; and flea larvæ have been reared in the sweepings of the carpets.

Under the Cleansing of Persons Act of 1897, Sanitary Authorities may make provision for freeing persons from vermin, and for this purpose arrangements are made whereby the verminous individual may receive a bath while the clothing is being steam disinfected. It is often found necessary to deal with the person's home on the same day as that on which the person is cleansed. Again, under the Children Act of 1908 power is given to obtain the cleansing of verminous school children. It is difficult to speak too highly of the value of this work, and of the good services which school nurses perform in respect to verminous

children; for not only are vermin dangerous and demoralizing, but by robbing children of rest and sleep they render many mentally unfit to properly respond to educational influences. The preventive measures may be briefly defined as follows:—

In the first place it is desirable that the homes of the poorer class should be made as vermin-proof as possible, by avoiding wooden skirtings, mouldings, etc., and even wall-papers, unless these are sized and varnished. It cannot be too strongly impressed that a verminous house is a dirty house, and that one of the greatest preventive measures against lice and bugs is cleanliness. Verminous bedding and clothing can only be satisfactorily dealt with by steam disinfection. The infected rooms may then be fumigated with sulphur, three pounds of sulphur being burnt to every 1,000 cubic feet of space. Subsequently to this the rooms should be thoroughly washed, and iron bedsteads and wire-mattresses, etc., exposed to a plumber's blow-lamp or brushed over with a strong solution of the perchloride of mercury and rectified spirit or petroleum; the raking of cracks in the floor boards and the dusting in of dry powdered lime is also of service, and old wall-papers must generally be removed. Of the odorous substances which discourage fleas and bugs, the essence of thyme appears to be the most efficacious.

The Disposal of the Dead.

Cremation is the most sanitary method of disposal of the dead. The method is of great antiquity, and was commonly employed by the ancient Greeks and Romans. The body can by this method be reduced, within the space of two hours, to a small quantity of odourless ash, which can, if the relatives of the deceased so desire, be preserved in sealed urns in a columbarium adjacent to the crematorium. Cremation, too, prevents the pollution of the ground—a pollution which is of a dangerous character when the bodies of those who have died of infectious diseases are interred.

This method of disposal of the dead is making progress in this and other countries, and several crematoria have been provided in Great Britain during recent years. Temperatures of 1,800° to 2,000° F. are now attained in the furnaces; and the heated gases from the furnace perform their work in under two hours.

The main objections which are raised against cremation at the

present day are based on sentimental and religious grounds, which time and education will remove, for the ultimate effects of cremation and earth burial are precisely the same. In earth burial the ultimate resolution of the body into its component elements may take a year or many years to accomplish, whereas by incineration the same products are formed in as many hours. These products are largely gaseous, and whereas in cremation special provision is made to completely burn them up without offence, in earth burial they necessarily pollute the soil, and escape into the general atmosphere. There are only two real objections which can be raised against cremation—namely, the cost of the process, and the fact that the complete destruction of the body involves also the destruction of evidence of certain crimes. As regards the first objection, the original cost of erection of a crematorium is considerable, and the working expenses are high; but, where there is a crematorium within easy access by road or rail, cremation can now be carried out at about the same cost as earth burial. To meet the second objection, State officials could be appointed, as in France and Germany, to inquire into and verify the death certificates; and, as a means to the same end, the English Cremation Society has drawn up a code of very stringent rules (including two independent certificates of death) which must be complied with before a body can be cremated.

Earth Burial.—This method causes pollution of both soil and air, and should be discontinued within the borders or in the near neighbourhood of towns and thickly populated districts. As the old burial grounds in towns become filled up they have to be closed, and these can then be converted into open spaces and garden recreation grounds. Burial sites at a distance from the town must then be provided, at great cost and much inconvenience to the ratepayers.

It is necessary, in order to carry out earth burial under the most favourable conditions, to provide from a quarter to half an acre of land to every 1,000 of the population for some fourteen years, according to the suitability of the soil for the purposes of interment.

A sandy and calcareous loam is the best soil for a graveyard; a stiff clay, which retards dissolution, is the worst. In clay sites, moreover, the ground is liable to crack in very dry weather, and the gases of putrefaction may then find a direct outlet to

the surface of the burial ground. Coarse gravel, comparatively free from any binding material, and broken rock are too loose and open to constitute good soils for burial sites; and chalk is contra-indicated on account of the risk of fissures transmitting impurities to the air above or to a water supply below. An isolated tract of ground, with good surface falls for natural drainage, and having a considerable thickness of fine sand and sandy loam, or sandy and loamy gravel, resting upon a deep bed of clay, would constitute an ideal site. The earth should have a depth of not less than 10 feet, and graves should never be dug deeper than 8 feet from the surface. In every case a space of at least 2 feet should intervene between the bottom of the grave and the surface of the subsoil water.

As at present practised, with the use of lead shells and strong wood coffins, the method of earth burial preserves the bodies for a very long period. Nothing whatever is gained by this lengthy preservation; and the aim of rational earth burial should be to facilitate the ultimate reduction of the body into its component elements. To this end, the body should be placed in an easily perishable coffin of wickerwork or of unprepared wood, and the grave should not be deeper than 3 to 5 feet from the surface—the earth being very much more active as a destructive and purifying agent in the upper layers, not exceeding 5 feet in depth from the surface, than it is at greater depths.

By the use of quicklime in earth burial the soft tissues of the body are rapidly destroyed, and the process of decomposition is completed at a comparatively early period.

Other methods of disposing of the dead are:—(1) By simple exposure to the air, as practised by the Australian aborigines, (2) committal to the sea; (3) the exposure of the body in the sun and open air—the fleshy parts may be eaten by vultures, a method followed by the Parsees of India in their "Towers of Silence"; (4) desiccation or mummification.

Embalming was commonly practised in ancient Egypt. The abdominal viscera were extracted by incision on the left side, and the cavity was then cleansed with palm oil and filled with myrrh, cassia, and other odoriferous substances. The body was ultimately wrapped in very numerous layers of cloth and sealed up hermetically. In the modern method of temporarily preserving bodies the vascular system is first of all injected with a preservative fluid, it being a common practice to inject into the

carotid artery some 6 to 8 pints of a mixture, consisting of carbolic acid 1 part, glycerine 10 parts, alcohol 50 parts, and water 40 parts. The cavities of the chest and the abdomen are emptied and washed with camphorated spirit; the organs are then similarly washed and injected with some preservative fluid before they are replaced. The surface of the body should be lubricated with vaseline containing 5 per cent. of carbolic acid, and it is advisable to fill the cavities of the body with cotton-wool soaked in glycerine containing 5 per cent. of carbolic acid.

A more recent method of preserving bodies is by exposure for 3 or 4 weeks to the vapour of formic aldehyde (Rechter's method). Underneath the open wire shelf, on which the body rests in the sterilizing chamber, an ice closet is placed, in order to inhibit by cold the action of the intestinal bacteria, until the formic aldehyde vapour begins to produce a distinct antiseptic effect.

Cemeteries, Earth Burial, and Cremation.

Information of a death must be given to the Registrar of Births and Deaths within five days; or, when a notice is sent along with a medical certificate, within fourteen days.

By the Public Health (Interments) Acts, 1879, both urban and rural authorities may provide cemeteries for their districts, and must do so if required by the Local Government Board on the ground of inadequacy of existing burial places, or of these being a danger to the public health.

The Act forbids the construction and laying out of a cemetery within 200 yards of any dwelling house, unless with the consent of the owner and the occupier of such house.

An existing burial ground may be closed by the Home Secretary by Order in Council under the provisions of the Burial Act, 1853. Interments within the walls of churches built after 1848 are forbidden by the Public Health Act, 1875.

The Regulations for Burial Grounds issued by the Home Secretary in 1863 provide, *inter alia*—(1) For the fencing and under-draining of the site, to prevent water rising into any grave; (2) grave spaces to be laid out, and a corresponding plan kept, such spaces to be 9 feet by 4 feet for adults, and 4½ feet by 4 feet for children under twelve years; (3) a register of graves is to be kept; (4) a body buried in a walled vault is to be cemented in, and never afterwards disturbed; (5) only one body to be buried in a grave at one time, unless members of the same family; (6) no grave to be reopened until fourteen years have elapsed for an adult, or eight years for a child, unless to bury another member of the same family, in which case at least 1 foot of earth is to be left undisturbed over the previously buried coffin; (7) no adult body to be buried within less than 4 feet of the level of the ground; a child under twelve may be buried within 3 feet.

By Section 141 of the Public Health Act, 1875, local authorities may make by-laws for the management of cemeteries.

The Cremation Act, 1902, gives powers to burial authorities to provide and maintain crematoria. The site and plans of the crematorium must be approved by the Local Government Board, and the crematorium must be certified by the burial authority to the Secretary of State to be complete and properly equipped, and built in accordance with the plans. No crematorium may be constructed nearer than 200 yards to any dwelling house, except with the consent of the owner and occupier of such house; nor may it be within 50 yards of any public highway, nor within the consecrated part of the burial ground of any burial authority. The Secretary of State makes regulations as to the maintenance and inspection of crematoria, and as to the practical working of the cremations.

CHAPTER XIV

STATISTICS

Statistical Inquiries.

The science of statistics consists in the collection of individual facts, with the view of grouping them into different classes according to certain definite characters they possess. The rule to which attention must be specially directed, in differentiating a series of facts, is that the points of difference or characteristics on which a group is to be formed should be common to each member of that group, but absent from the members of all other groups. The dividing character must be constant, and must be definite.

It does not follow that, because in any series of cases the groups bear a certain numerical proportion to the total number of cases, these proportions will be the same in any subsequent series of like cases, unless the numbers dealt with in the first cases are infinitely large.

The relative values of two or more series are as the square roots of the number of units of observation; and thus by increasing the number of observations in any inquiry, the value (or accuracy) increases as the square root of the number.

The smaller the number of individual facts on which the groups are founded, the greater is the possible deviation from the proportions which may be observed in any subsequent series of like facts. By *Poisson's Rule* the limits of error, or the degree of approximation to the truth of the numerical relations existing between the units or groups of a series, may be ascertained.

Let M = total number of cases in the series recorded.

,, m = number of cases in one group

,, n = number of cases in the other group.

Then $m+n=M$, and $\frac{m}{M}$ and $\frac{n}{M}$ are the proportions of each

part to the whole. But on subsequent occasions, with another series of like cases, the proportions may be:

$$\frac{m}{M} + 2\sqrt{\frac{2.m.n}{M^3}}\ ;\ \text{or}\ \frac{m}{M} - 2\sqrt{\frac{2.m.n}{M^3}}.$$

And the same holds good with n group of cases. The larger the value of M, the less will be the value of the fraction of which M^3 is the denominator, and consequently the smaller the limit of error.

Example.—

M = 100 cases of fever.
m = 25 cases which die.
n = 75 cases which recover.

Then the proportion $\frac{m}{M}$ or $\frac{1}{4}$ of fatal cases may be in other instances:

$$\tfrac{1}{4} + 2\sqrt{\frac{2 \times 25 \times 75}{100^3}} = 0{\cdot}25 + 0{\cdot}1225 = 0{\cdot}3725;$$

$$\text{or } \tfrac{1}{4} - 2\sqrt{\frac{2 \times 25 \times 75}{100^3}} = 0{\cdot}25 - 0{\cdot}1225 = 0{\cdot}1275.$$

That is to say, in 100 other cases of the same fever, instead of the deaths being 25, they may be as many as 37, or as few as 13.

The arithmetical mean of a series of figures is obtained by adding together the numerical values of the figures, and dividing the total by the number in the series. This mean number will have a higher numerical value than belongs to some of the figures composing the series, and a lower numerical value than belongs to others. The less the difference between the mean and the figures of the series, the greater is its value, and the more closely does it conform to a true average. The relative values of two or more similar series are as the reciprocals of the squares of the probable errors: that is as $\frac{1}{(pe)_2}$, where pe is the probable error. The probable error is approximately two-thirds of the mean error, and implies that, if the series were prolonged indefinitely, the error would probably exceed or fall short of this mean to the proportion indicated by the figure of the probable error. The mean error is obtained as follows: 1. Find the *mean* of the series of observations; find the *mean* of all the observations *above* the mean, and subtract the mean from it; this gives the mean error in excess. 2. Find the *mean* of all the observations *below* the mean, and subtract the latter from the

mean; this gives the mean error in deficiency. Add the two quantities (mean error in excess and mean error in deficiency) and take the half.

The various means are:

The arithmetical mean $= \dfrac{a+b+c+d+e}{5}.$

The geometrical mean $= \sqrt[5]{a\ b\ c\ d\ e}.$

The harmonic mean $= \dfrac{5}{\frac{1}{a}+\frac{1}{b}+\frac{1}{c}+\frac{1}{d}+\frac{1}{e}}.$

The quadratic mean $= \sqrt{\dfrac{a^2+b^2+c^2+d^2+e^2}{5}}.$

If the terms of the series are equal, the above means are all identical. If the terms are unequal, the quadratic mean is the highest, the arithmetical comes next, and then follow the geometrical and harmonic means.

The value or reliability of an average or arithmetical mean is evidently dependent upon the degree of approximation between the average and the various factors embraced. Thus, in two streets A and B, each containing 20 houses, the average number of persons per house in each street may be the same, but the value of the average in its applicability to any particular house in each of the two streets may be very different. Thus, if in street A 10 houses have 8 inhabitants, 6 have 4, and 4 have 2, the average is 5·6 persons per house; whilst in street B 1 house has 7 inhabitants, 10 houses have 6, and 9 houses have 5, the average again is 5·6 per house. These figures per house may be called "variables," and the extent to which these variables, on an average, deviate from the mean is called "the standard deviation." The value of the mean is, according to biometricians, in inverse ratio to the *standard deviation* (usually denoted σ), which is obtained by the following mathematical formula:

$$\sigma = \sqrt{\frac{n_1 a_1{}^2 + n_2 a_2{}^2 + n_3 a_3{}^2 \cdots\cdots\cdots}{N}}$$

in which n_1 n_2, etc., are the number of factors having the same values or measurements, and a_1 a_2, etc., are the number of units separating each group value from the mean value of the whole N.

The standard deviation in the case of street A will be found to be 2·5, whilst in the case of street B it is only 0·18.[1]

The factors in these equations are obtained as follows:

Taking street A, 2·4 = the difference between 8 and 5·6; and 1·6 that between 4 and 5·6; and 3·6 that between 2 and 5·6.

The two standard deviations above given are comparable, because the arithmetical means coincide. But in the event of two means disagreeing, the standard deviations can only be made comparable by expressing them as a percentage of their corresponding means, the figure thus obtained being called "*the coefficient of variation*." Thus, if we compare streets A and B with another street C of 20 houses, of which 10 houses have 7 inmates, 6 houses have 6 inmates, and 4 houses have 5 inmates, the average per house is 6·3 persons, and the standard deviation is 0·25. The coefficients of variation of A, B, and C respectively are $\frac{2 \cdot 5}{5 \cdot 6} \times 100$, $\frac{0 \cdot 18}{5 \cdot 6} \times 100$, and $\frac{0 \cdot 25}{6 \cdot 3} \times 100$, or 44·6, 3·2, and 4·0.

Correlation.—Series of phenomena are said to be correlated when certain values of one phenomenon occur more commonly with given values of the other. The correlation may be positive or negative. If the increase in the values of one series of phenomena is associated with an increase in the other, the correlation is positive; but if the increase in the one series is associated with a decrease in the other, the correlation is negative.[2] Thus there is positive correlation between summer diarrhœa prevalence and the temperatures of the air and earth, whilst there is negative correlation between summer diarrhœa and rainfall. The study of correlation has for its object the determination of a quantitative measure of the degree of association of the phenomena observed, it being clearly understood that the correlation of phenomena in no sense implies that they stand to one another in the relation of cause and effect, but that there is similar association of the variables composing the phenomena. The *coefficient of correlation*, when it is positive, is any figure between 0 and +1. If the phenomena are identical in their variables,

[1] (A) $\sigma = \sqrt{\frac{10 \times 2 \cdot 4^2 + 6 \times 1 \cdot 6^2 + 4 \times 3 \cdot 6^2}{20}} = 2 \cdot 5.$

(B) $\sigma = \sqrt{\frac{1 \times 1 \cdot 4^2 + 10 \times 0 \cdot 4^2 + 9 \times 0 \cdot 6^2}{20}} = 0 \cdot 18.$

[2] See paper by Dr. J. M. Troup and Mr. G. D. Maynard, on "Modern Statistical Methods" (*Lancet*, May 14, 1910).

the curves representing the variables will also be identical, and the coefficient (r) is $+1$; if there is no correlation, then $r=0$. Similarly complete negative correlation is indicated by $r=-1$, and all degrees of negative correlation lie between -1 and 0.

The probable error of a *coefficient of correlation* is usually expressed as—

$$0{\cdot}6745 \times \frac{1 - r^2}{\sqrt{N}}.$$

r = the coefficient.

N = the number of cases dealt with.

If only a few cases have been considered and the coefficient is, say, only 0·1, then it is quite possible that really there is no correlation at all, as the accuracy is directly proportional to the number of cases under observation.

Theory of Probability.—The object of the theory of probability is to obtain an accurate measure of the likelihood of the occurrence of events under conditions some of which are known and some unknown. Algebraically the probability of the occurrence of an event is expressed by a fraction, the numerator of which represents the number of ways in which the event can happen, and the denominator the sum of the number of ways in which it can happen and in which it can fail.[1] Since the sum of the two probabilities—the event happening and the event failing—is unity, the measure of the probability may vary from unity to zero—unity denoting absolute certainty of the occurrence, zero absolute certainty of its non-occurrence.

Thus, supposing that, on the average, of men aged twenty to thirty-five years in military service, who contract tubercle of the lung, 20 per cent. recover and 20 per cent. die whilst with the colours, whilst 60 per cent. are invalided out of the service, the probabilities of recovery and of death are equal—namely, $\frac{1}{5}$—whilst the probability of being invalided is $\frac{3}{5}$; or, in popular language, the odds are 5 to 1 each against recovery or death, and 5 to 3 against being invalided.

In medical, vital, and public health statistics, series of phenomena are often claimed to be related to one another, or to stand in relation to one another as cause and effect, without any account being taken of the possibility that the phenomena may be chance distributions explainable under the theory of probability. Thus the mortality or proportion of deaths to recoveries

[1] "Modern Statistical Methods," by Troup and Maynard.

(case rate) in the course of an epidemic of any disease may vary with the progress of the epidemic, and this might be due to variation in virulence of the infection, to variation in resisting powers of the individuals attacked, or to other special circumstances affecting the locale or environment, but it might in whole or part be a chance distribution calculable under the formulæ applicable by the theory of probability.

Vital Statistics.

The uses of vital statistics are to obtain information as to the health of the people and as to the various diseases from which they suffer; to assist in the study of the good and evil conditions affecting them; and to furnish the necessary data for life assurance.

To obtain the statistics of a community which have relation to its public health, it is necessary to have a correct enumeration of the population, a complete registration of births and deaths, and a correct statement as to the cause of death, together with the age of every deceased person. The number of births and of deaths which take place in the course of a year are generally expressed in the form of rates, *i.e.*, so many births or so many deaths to 1,000 of the population.

The first inquiry, therefore, which becomes necessary is to ascertain for any community the number of those living during any year. The last census returns give the exact enumeration of the numbers living and their ages at the time the census was taken. If the population is stationary—the births equalling the deaths and no emigration or immigration taking place—the census returns are true for any subsequent year. In this country the births have, for a great number of years, exceeded the deaths and the emigrations, with the result of a steady increase of the population.

By the *Law of Population*, a population increases in regular geometrical progression when the births exceed the deaths and the ratio of the births and of the deaths to the population remains constant.

Example.—If the birth rate of a population numbering 5,000 is 30 per 1,000 and the death rate is 20 per 1,000, and these rates remain constant for ten years, the annual rate of increase is 10 per 1,000, or 0·01 per unit; *i.e.*, one person becomes 1·01 at the end of the year, or 1,000 persons become 1,010. The population at the end of the tenth year (the last term of the series in geo-

metrical progression) $= 5{,}000 \times 1{\cdot}01^{10} = 5{,}523$ persons. For the population at the end of the first year is $5{,}000 \times 1{\cdot}01$; at the end of the second year it is $(5{,}000 \times 1{\cdot}01) \times 1{\cdot}01 = 5{,}000 \times 1{\cdot}01^2$; at the end of the third year it is $(5{,}000 \times 1{\cdot}01^2) \times 1{\cdot}01 = 5{,}000 \times 1{\cdot}01^3$; and at the end of the tenth year it is $5{,}000 \times 1{\cdot}01^{10}$.

The population of England and Wales in 1843 was about half the population in 1901, consequently it took 58 years to double itself.

The term "increment of life" is sometimes employed to denote the excess of births over deaths in a population, and if the balance is on the opposite side it is sometimes referred to as the "decrement of life."

Sometimes the terms "effective" and "specific" are applied to a population. The "effective" population is the population between the ages of twenty and seventy, and the "specific" population is the number of persons to each acre or square mile, which is the same thing as the density of the population. This is more usefully stated as the average number of persons occupying a room.

In calculating birth rates or death rates for any year, the estimated population for the middle of that year must be taken as the basis; for it alone represents the average number of persons who are living throughout that year. The following method is used by the Registrar-General for estimating from the last two census returns the population of a town or district for the middle of any year:

Example.—Suppose the population of a town by the census of 1891 is x, and by the census of 1901 is y, and it is required to know the population in the middle of the year 1905. Then the log. y − log. x = log. of the rate of increase for 10 years. This divided by 10 will give the log. of the rate of increase for 1 year. From the end of the first quarter of 1901 (when the census was taken) to the middle of 1905 is $4\frac{1}{4}$ years, and therefore the log. of the population in the middle of 1905 = log. of the population in 1901 + ($4\frac{1}{4}$ × log. of 1 year's increase). The number corresponding to this logarithm will give the calculated population.

This method assumes that the population of the town is increasing or decreasing in the same ratio since the last census as it did between 1901 and 1911. It is here that a fallacy may arise. Thus the population which serves as the basis for calculating the birth and death rates in the ten years intervening between any two census returns is only an estimate, and therefore only approximately true. The estimates of

population so obtained generally exhibit a considerable divergence from the actual truth in the years most remote from the last census. Consequently, statistics calculated upon such estimates are usually erroneous. A comparison may be made between this estimate and that arrived at by a calculation of the number of inhabited houses in the districts, as obtained from the rate books, and the average number of inhabitants in each, as shown by the last census; but this, again, is only an approximation. The average number of persons per inhabited house may vary from 4·5 to 9, according to the size of the house and the class of property. One individual should be allowed to each empty house, in order to account for caretakers and their families. Another means of checking the estimated population is by the birth rate, if this remain fairly constant in a series of years; and this computation is found generally to approximate closely to the truth, when applied to large populations. Thereby the population =

$$\frac{\text{registered births in the year} \times 1{,}000}{\text{average birth rate for previous 5 years}}.$$

An annual birth rate or death rate is calculated from the number of births and deaths respectively, multiplied by 1,000, and then divided by the population. The births or deaths are thus expressed as so many to every thousand persons living.

Birth rates and death rates may be calculated as annual rates to 1,000 persons living from weekly, monthly, or quarterly returns. When the returns are for a less period than a year, the rate represents the number of births or deaths that would take place per 1,000 of the population in a year, if the proportion of births or deaths to population recorded in these shorter periods were maintained throughout the year. Now, the correct number of days in a natural year is 365·24226, and the correct number of weeks is 52·17747. The death rate may therefore be calculated from weekly, monthly, and quarterly returns as follows:

A weekly death rate =

$$\frac{\text{number of deaths recorded in week} \times 52{\cdot}17747 \times 1{,}000}{\text{population}};$$

a monthly death rate =

$$\frac{\text{number of deaths recorded in four weeks} \times 13 \times 1{,}000}{\text{population}};$$

a quarterly death rate should deal with the thirteen weeks which most nearly correspond to the natural quarter, and =

$$\frac{\text{number of deaths recorded in quarter} \times 4 \times 1{,}000}{\text{population}}.$$

A better method of stating the birth rate than that of the ratio of births per annum to 1,000 of the population is to state the proportion of births per 1,000 women of conceptive age, *i.e.*, 15 to 45 years. This is sometimes called the "corrected" birth rate. If this method is adopted it is desirable to carry the analysis further, and to ascertain also the proportion of legitimate births per 1,000 married women aged 15 to 45, and the proportion of illegitimate births per 1,000 unmarried and widowed women of similar age.

In large towns a certain number of deaths occur in public institutions (hospitals, workhouses, etc.), which have to be allotted to the districts in which the deceased persons resided. In London, for instance, which is divided into a number of boroughs, in calculating the death rate of any borough, the deaths of non-parishioners which occur in public institutions in the borough must be excluded; whilst deaths of parishioners occurring in the public institutions in the borough and outside it must be included, in order to arrive at the true death rate. In London, the figures required for this purpose are now supplied to medical officers of health from the Registrar-General's office. Formerly it was the custom to assign to each sanitary area, out of the total deaths in public institutions in London, a number proportional to its population.

In estimating the total death rate of a combination of two or more districts, which exhibit different mortality figures, the method of taking the average of the district death rates, irrespective of population, would introduce a serious error.

Example.—If A has a population of 10,000 and a death rate of 25 per 1,000; if B has a population of 2,000 and a death rate of 10 per 1,000; and if C has a population of 7,000 and a death rate of 15 per 1,000, the death rate of the combined districts with a population of 19,000 is—

$$\left(\frac{10{,}000}{19{,}000} \times 25\right) + \left(\frac{2{,}000}{19{,}000} \times 10\right) + \left(\frac{7{,}000}{19{,}000} \times 15\right) =$$

$$\left(\frac{10}{19} \times 25\right) + \left(\frac{2}{19} \times 10\right) + \left(\frac{7}{19} \times 15\right) =$$

$$\frac{250 + 20 + 105}{19} = \frac{375}{19} = 19{\cdot}7.$$

If, however, the average of 25, 10, and 15 had been taken—viz., 16·6—an error of 3·1 per 1,000 would have been committed.

It may be well to point out in this place—especially as misunderstanding is constantly arising on the subject—what is the true significance of death rates, and how far they are reliable as tests of the health and sanitary surroundings of different communities.

Death rates constructed from the mortality returns of short periods, such as a week or month, are not reliable as tests of health. They are necessarily subject to accidental fluctuations, which must prevent any true conclusions being drawn from them. So, too, with the death rates of very small populations, even when they exhibit returns covering a period of a year. The numbers on which the figures are founded are not sufficiently large to exclude those accidental fluctuations from varying circumstances which must be got rid of before any just reasoning can be founded on death rates. It is different with the death rates from yearly returns of larger populations. Where the units on which the figures are founded are sufficiently large, accidental fluctuations are submerged, so to speak; and the errors traceable to them are reduced to such small limits that trustworthy conclusions can be drawn.

But, in comparing death rates of different towns or districts with each other, there are other sources of error which must be taken into account. A population consists of a number of people living at every age, from the time of birth to one hundred years or more. Now, the age distribution of two or more populations may vary widely, the proportions of children, adults, and old people to the total population being often very different. If the death rate were the same for all ages, this different age distribution might be neglected. But such is not the case; children under five and old people over fifty-five years of age die at a greater rate; while those from the age of five up to fifty-five die at a less rate than that represented by the general rate. There is another disturbing factor, and that is the proportionate number of males to females in any population. Females at all ages have lower death rates than males, except in the age period five to fifteen, when the female rate is slightly higher. The causes of the higher male mortality are chiefly to be found in their more exacting and dangerous occupations and their greater indulgence in alcohol. The census of 1911 showed that there were 106·9 females to every 100 males in the population of England and Wales.

The following table exhibits the death rates at different age periods (calculated upon the numbers living at each age period) amongst males and females in England and Wales:

ENGLAND AND WALES DURING THE YEAR 1913.

	Males	Females.
All ages	14·8	12·0
Under 5 years	39·2	32·2
5–10	3·1	3·1
10–15	1·9	2·0
15–20	2·7	2·5
20–25	3·5	3·0
25–35	4·6	3·8
35–45	8·0	6·5
45–55	15·0	11·5
55–65	30·7	23·0
65–75	64·5	51·1
75–85	140·4	117·5
85 and upwards	266·8	241·0

(From the Annual Reports of the Registrar-General.)

From these figures it will be seen that it would not be right to compare the general death rates of two towns, one of which, let us suppose, had a larger proportion of females and of young adults, and a smaller proportion of males and old people, than the other. Corrections must therefore be made for differences in the age and sex distribution. It is for this reason that the uncorrected death rates of rural districts overstate, whilst the death rates of large cities understate, the real mortality.

Besides normal increase of population by excess of births over deaths, the immigration into large towns, which always greatly exceeds the emigration from them, tends to bring large numbers of young adults into the population, and so influences the age distribution.

The following table gives the age distribution of 1,000 persons in England and Wales (1913):

All ages	1,000	25–35	165
Under 5 years	107	35–45	134
5–10	103	45–55	98
10–15	97	55–65	64
15–20	93	65–75	38
20–25	88	75 and upwards	13

The Registrar-General has adopted the following method for making the necessary corrections for age and sex distribution in any population (Annual Summary, 1883):

The standard death rate of the population is first obtained. This is a death rate calculated on the hypothesis that the mortality of the population at each age period and for each sex corresponds to that obtaining in England and Wales as a whole. The facts as to the age and sex distribution of the population of any area are ascertained from the last census returns, and thus the population can be split up into the numbers living of both sexes at the different age periods. Then, for the purpose of calculating the standard death rate of the district, it is assumed that those living in each of the groups will die at the same rate as those dying in the similar age periods in England and Wales generally; and thus a hypothetical number of deaths is arrived at. The total deaths thus calculated $\times$ 1,000, and divided by the population under consideration, will furnish the standard death rate. Now, it is obvious that if any town has the same relative proportions of males and females in the different age periods as England and Wales, then, if the mortality rates of England and Wales for each of these age periods and for both sexes are applied to these proportions, the standard death rate of that town will be the same as the death rate of England and Wales. Any difference, therefore, can only be due to the fact that the town population has a different age and sex distribution.

The death rate of England and Wales is therefore divided by the calculated standard death rate; and thus a factor is obtained which, when multiplied into the recorded death rate, serves to make allowance for differences of age and sex distribution, and to furnish a corrected death rate—comparable with that of England and Wales and of other towns corrected on the same basis. As an example of the method of arriving at a corrected death rate, the table on p. 747 may be given (Newsholme's *Vital Statistics*).

The standard death rate for Huddersfield is (see Table) $\frac{1,572 \times 1,000}{95,420} = 16\cdot47$ per 1,000. The annual death rate of England and Wales in 1881-90 was 19·15. The factor for correction for Huddersfield is, therefore,

$$\frac{19\cdot15}{16\cdot47} = 1\cdot1627.$$

The age and sex distribution of Huddersfield is thus seen to be more favourable to a low death rate than that for the country as a whole; and when the recorded death rate is multiplied by

the factor and brought into comparison with the death rate of England and Wales, it is thereby increased. As a general rule, in rural districts the age and sex distribution of the population is less favourable to a low death rate than that in urban districts (Newsholme).

Ages.	Mean Annual Death Rate of England and Wales, 1881–90, per 1,000 living at each Group of Ages.		Population of Huddersfield in 1891.		Calculated Number of Deaths in Huddersfield.	
	Males.	Females.	Males.	Females.	Males.	Females.
Under 5 ..	61·59	51·95	4,551	4,785	280	249
5–	5·35	5·27	4,691	5,081	25	27
10–	2·96	3·11	5,113	5,165	15	16
15–	4·33	4·42	4,905	5,549	21	25
20–	5·73	5·54	4,541	5,461	26	30
25–	7·78	7·41	7,466	8,834	58	65
35–	12·41	10·61	5,576	6,265	69	66
45–	19·36	15·09	3,944	4,649	76	70
55–	34·69	28·45	2,393	3,017	83	86
65–	70·39	60·36	1,128	1,590	79	96
75 and upwards	162·62	147·98	250	466	41	69
Totals ..	..	..	44,558	50,862	773	799
			95,420		1,572	

The factor for correction exceeds unity in twenty-six out of the twenty-eight large towns of the Registrar-General, thus showing that their death rates without correction are understated; and the factor is less than unity in the remaining two towns, in these two cases the uncorrected death rates being overstated compared with the country generally.

The comparative mortality figure is a useful means of expressing a comparison of the mortalities of different districts. For any year it is—

$$\frac{\text{the corrected death rate of the district} \times 1{,}000}{\text{death rate of England and Wales}}$$

Taking Huddersfield, again, as an example: the death rate of England and Wales for 1897 was 17·43, and that for Huddersfield was 19·07; the comparative mortality figure of that town for 1897 was, therefore:

$$\frac{19{\cdot}07 \times 1{,}000}{17{\cdot}43} = 1094.$$

This implies that, after making allowance for age and sex distribution of the population, the number of living persons

that in England and Wales in 1897 furnished 1,000 deaths, in Huddersfield furnished 1,094.

The number of males and females living, and the mean death rates at the twelve age periods, among a million persons in England and Wales, has been termed the "Standard Million."[1] This is also of great utility as a uniform standard of comparison of the mortality of different districts with one another and with the whole country.

Having ascertained the death rate for the age and sex groups in the population of a given district, the number of deaths which would have occurred in each of the similar age and sex groups of "the standard million," if subject to the same mortality, is calculated. From the sum of these deaths a death rate is calculated for the district, and this is termed the "corrected" death rate, for it is the death rate which would have prevailed had the age and sex distribution of the population of the district been the same as that of England and Wales as a whole.

In many parts of large towns the density of population is very great—200 persons to an acre or more—and the death rate correspondingly high. The high death rates which go with dense population are not simply the result of aggregation. Aggregation means, no doubt, generally polluted air and possibly polluted water and soil, and the easy spread of infectious disease. But, as Dr. Ogle has pointed out, the more crowded a community, the greater the amount of abject want, filth, crime, drunkenness, and other excesses, the more keen is the competition, and the more feverish and exhausting the conditions of life. It is, too, in these crowded communities that the most dangerous and unhealthy industries are carried on. These indirect consequences of aggregation influence the mortality greatly more than the direct.

The death rate from a disease affecting only a particular class should be expressed as the number of these deaths to every 1,000 of those who are liable to contract the disease. The death rate from puerperal fever, for instance, should be taken as

$$\frac{\text{the deaths from puerperal fever} \times 1{,}000}{\text{the number of registered births}},$$

since it is only those females who have recently been delivered of a child who are liable to die from this complaint.

[1] *Vide* Supplement to the 55th Annual Report of the Registrar-General.

The general death rate fluctuates considerably throughout the year. In large communities it is generally high through January, February, and March, and falls considerably through April, May, and June. It often rises again through July and August, to fall in September and October, and it again rises in November and December.

Mild winters and cool summers favour a low death rate, from the lessened mortality from respiratory diseases and intestinal diseases, respectively.

In determining the cause of death or the origin of an outbreak of disease, much more than the mere concurrence of two phenomena is required to prove their relation as cause and effect. The inductive methods of agreement, of difference, and of concomitant variations must be worked through, and the possibility of a plurality of causes should never be lost sight of.

The number of deaths at a special age period must not be stated as a proportion of the total population, for a fallacy is involved in attempting to establish a relationship between two factors, both of which are variable. The number of deaths at a certain age period must be expressed as a proportion of the number living at the age in question, this number—as we have seen—varying considerably in different communities. The special disease, also, may be one affecting chiefly a certain age period and sex, and a like error will be involved if the rate is not expressed as per 1,000 of the population living at the same ages and of the same sex as those attacked.

Thus, more than 90 per cent. of the deaths from scarlet fever occur among children under ten years of age. Now, children under ten amount to 25 per cent. of the population of Berlin, but only to 12·4 per cent. of that of Paris. An equal death rate from scarlet fever, calculated upon the entire population of the two cities, would, therefore, imply a mortality twice as great in Paris as in Berlin.

The annual birth rate in England and Wales was 22·4 per 1,000 in 1921. The birth rate has declined since the year 1876, when it was 36·3 per 1,000, and the highest recorded rate of any year since civil registration began (1839). The illegitimate birth rate was, in 1920, 1·2 per 1,000 births; and of the total births, the two sexes were in the proportion of 1,052 males to 1,000 females.

The deaths assigned to pregnancy and child-birth furnished, in 1920, a rate of 4·3 per 1,000 births.

In 1920, 20·2 persons were married per 1,000 of the population in England and Wales. The marriage rate fell continuously from the year 1873 (17·6 persons married per 1,000) to the year 1886 (14·2 per 1,000), but has since slightly risen again.

The lowest annual death rate in England and Wales ever recorded since civil registration began was in the year 1921, the rate being 12·1 per 1,000. A high mortality prevailed in the four years 1890, 1891, 1892, 1893, the average death rate being 19·5 per 1,000, which is attributable to the prevalence of influenza in those years and to a great fatality from lung diseases, the sequelæ of influenza.

The mean annual death rate of the ten years 1861-70 was 22·5 per 1,000; of the ten years 1871-80, 21·4 per 1,000; of the ten years 1881-90, 19·1 per 1,000; and of the ten years 1891-1900, 18·2 per 1,000. The mean rate for the ten years 1901-10 was only 15·4, and for the three years 1911-13 also 15·4. Although to a great extent this lowered death rate must be credited to the operation of the Public Health Acts, and the more stringent application of these Acts and of local by-laws, still, it must not be forgotten that the lowered birth rate would conduce to a lowering of the death rate for some few years at least, as the proportion of children under five years of age, whose death rate is high, would be diminished, and the ratio of older children and adults to the entire population would be increased. If the birth rate continues to fall, as it has done in the last twenty years, we may expect the death rate eventually to rise again, owing to the increase in the mean age of the population, and a consequently increased ratio of old people (over fifty-five years) to the total population.

The leading causes which serve to raise the death rates of towns above those in country districts are as follows: overcrowding, which directly causes disease and promotes the spread of communicable illness, especially summer diarrhœa, measles, and phthisis; the higher birth rates, attended with a higher rate of infantile mortality, and a higher zymotic death rate; the less healthy occupations; the greater amount of profligacy and intemperance; the larger number of accidents; the existence of many public and private institutions for the reception of the sick, which attract people from the neighbouring rural districts, and the fact that some of the deaths occurring in these institutions may not be allotted to the districts from which the sufferers came.

DEATHS FROM PRINCIPAL CAUSES (ENGLAND AND WALES), 1920.

Disease.	Proportion per 1,000 Deaths from all Causes.
1. Measles	15
2. Whooping-cough	9
3. Diphtheria, croup	12
4. Influenza	23
5. Phthisis, pulmonary tuberculosis	72
6. Other forms of tuberculosis	19
7. Cancer	94
8. Diseases of nervous system and special sense ..	102
9. Organic heart disease	105
10. Other diseases of circulatory system	42
11. Bronchitis	82
12. Pneumonia	80
13. Other diseases of respiratory system	13
14. Diarrhœa and enteritis	25
15. Other diseases of digestive system	38
16. Diseases of genito-urinary system	38
17. Premature birth and diseases of early infancy	62
18. Old age	57
19. Injuries and accidents (violence)	38
20. Other causes	74
Total	1,000

Pulmonary tuberculosis furnishes 79 per cent. of all the deaths from tuberculosis, and 7·2 per cent. of the deaths from all causes. The mean death rate from this disease for 1851-60 was 2·75 per 1,000; that for 1911-20 was 1·10.

We are now in a position to understand the influence of birth rate upon death rate. In large towns high death rates go with high birth rates; but, as pointed out by the late Dr. Farr, high death rates are not the result of high birth rates; they are more generally caused by density of population (overcrowding on space and in houses) and by bad sanitary conditions. High birth rates should cause a lowered death rate; for if year by year the births exceed the deaths amongst a population, not only are additional children under five years of age, whose mortality is high, added to the population, but a still larger increase of those between ten and forty, whose mortality is low, takes place and counterbalances the other; whilst the proportion of old people over fifty-five years of age to the total population is diminished. A high birth rate, therefore, continuing over a period of years, is favourable to a low death rate, and a low birth rate to a high

death rate. If we find—as is actually the case—that a rural district with a low birth rate has also a low death rate, whilst an urban district with a high birth rate has a high death rate, we must conclude that the sanitary surroundings, the occupations, or the social conditions of the rural districts are more favourable to life than those of the urban. These are the main causes of the varying health conditions of populations, of which death rates, with certain limitations, afford trustworthy evidence.

The higher birth rate in large urban districts is due to the following causes: the greater proportion of women at child-bearing ages, the higher marriage rate, the earlier marriages, and the greater infantile mortality. The state of national prosperity to a large extent determines the birth and marriage rates.

The marriage rate is usually expressed as

$$\frac{\text{number of marriages} \times 1{,}000}{\text{population}};$$

but it should more properly be expressed as the number of persons married annually per 1,000 marriageable persons—*i.e.*, those over fifteen years who are unmarried.

The marriage rate is highest in large towns to which many young adults emigrate from country districts, and where more constant labour at a higher rate of remuneration than in the country can be secured. The average annual fecundity of married women of reproductive ages is about 260 live births to 1,000 women.

Approximately 70 per cent. of the decrease in the birth rate during the past 35 years (based on the proportion of births to the female population aged 15-45) results from decreased fertility of married women, some part of this decrease being attributable to changes in their age constitution; about 10 per cent. may be ascribed to the decrease of illegitimacy, while the remaining 20 per cent. is due to the decrease in the proportion of married women of conceptive ages in the female population.

The tendency in modern times to postpone marriage to a later age than formerly is shown by the fact that in 1871 15·2 per cent. of the married women aged 15-45 were comprised in the group 15-25 years of age, whereas in 1901 only 12·4 per cent. of the married women were in this group. The later age of marriage for women curtails the period within which children can be born.

The best statistical evidence of the health of a community

is, of course, furnished by the corrected death rate, although a sick rate ("morbidity rate") would furnish still better evidence. The registration of sickness, however, would be open to many fallacies and abuses. The scant returns which are available in this country (*i.e.*, from sick clubs, friendly societies, industrial organizations, hospitals, army, navy, police, etc.) are only concerned with disabling sickness, among what are often selected lives, and are of little value for the purpose under consideration. On an average, there are two years of sickness suffered to each death registered.

ANNUAL DEATH RATE PER 1,000 IN 1871-80, 1881-90, 1891-1900, 1901-10, AND 1911-20.

	England and Wales (Persons).				
	1871-80.	1881-90.	1891-1900.	1901-10.	1911-20.
All causes	21·27	19·08	18·21	15·37	14·40
Small-pox	0·23	0·05	0·01	0·01	0·00
Measles	0·38	0·44	0·41	0·31	0·28
Scarlet fever	0·72	0·33	0·16	0·11	0·05
Diphtheria	0·12	0·16	0·26	0·18	0·14
Whooping-cough ..	0·51	0·45	0·38	0·28	0·18
Typhus	0·06	0·01	0·00	0·00	0·00
Enteric fever	0·32	0·20	0·17	0·09	0·04
Diarrhœa and enteritis ..	—	—	—	0·28	0·17
Phthisis	2·12	1·72	1·39	1·16	1·08
Other tubercular diseases	0·75	0·70	0·62	0·49	0·33
Cancer	0·46	0·58	0·75	0·90	1·12

The death rates from the principal zymotic diseases, from tuberculosis, phthisis, and acute diseases of the lungs, afford most valuable evidence of sanitary condition. *The zymotic death rate* is the number of deaths from the seven principal zymotic diseases multiplied by 1,000 and divided by the population. The seven principal zymotic diseases of the Registrar-General are small-pox, measles, scarlet fever, diphtheria, whooping-cough, "fever" (*i.e.*, typhus, enteric fever, and simple continued fever), and diarrhœa. Of these, enteric fever mortality is the best test of sanitary condition, caused as it is by specific fæcal contamination of soil and water; whilst diarrhœa, with its special incidence on young children, is notably associated with insanitary surroundings. The other zymotic diseases, although probably favoured in their onset and fatality by unhygienic conditions, also indicate, when the mortality from them is high,

a failure on the part of the sanitary authority to control their spread by disinfection and isolation. Tuberculosis, phthisis, and acute diseases of the lungs, are most prevalent and most fatal among communities where overcrowding in dwellings or workshops is allowed to exist, or where sites are damp and the subsoil saturated with water. They may thus be taken as evidence of a certain class of insanitary conditions, usually associated with poor town populations. The rate of infantile mortality, though influenced solely by conditions affecting those under one year of age, also ranks high as evidence of the health of a community.

The *mean age at death* of a population is obtained by adding together the ages at which people die, and dividing the number of years lived by the number of deaths. It is merely an expression of the average age at death of a population, and gives no evidence of the health or sanitary condition of the community. When a population is rapidly increasing by excess of births over deaths, the mean age at death is low, because the population is largely composed of young persons. When a population is nearly stationary, the proportion of old people to the total population is large, and the mean age at death is high. The mean age at death, therefore, gives information as to the ages of the dying and, *per contra*, of the living in different communities, but nothing more.

A *life table* represents a generation of individuals passing through life to extinction. The calculations of a life table relate to an arbitrary number of individuals supposed to be born simultaneously, and to exist under the same conditions as those which prevail in a given community. Usually the population is assumed to start with a million births, and these are divided into males and females in proportion to the actual number of births of either sex that have occurred in the given community during an intercensal period of ten years. The mathematical probability of survival of every individual for each year of life is then calculated from data obtained from the actual community, and thus the hypothetical life table population becomes the medium for the record of facts concerning the vitality of a given population.

The probability of survival from the beginning to the end of each age-period =

$$\frac{\text{the number of survivals at the end of the period}}{\text{the number living at the beginning of period}};$$

and for the purposes of a life table the numbers of either sex living at the end of each age-period may be obtained by multiplying the number commencing the period by the above fraction. By this means the numbers in each successive age-period are gradually diminished to extinction, since the factor is always less than unity. The column of the life table showing the number of survivors at each age-period for both sexes is thus obtained. It need hardly be said that the larger the number of the population involved, and the longer the period of time from which the data of the population are obtained, the more reliable will be the various estimations of the life table. Hence it is a common practice to take the mean figures, both as to population and deaths at different ages, from the accumulated data of two censuses and the intervening years. But the above facts are first obtained in five and ten yearly age-and-sex groups of the population, so that the lives and deaths of each age-group have to be distributed artificially to each year of age included in the groups. The fact that several methods may be adopted for this distribution accounts for the main differences in construction of various life tables. In many tables the "graphic" method has been adopted. The method is briefly as follows:—On paper ruled into equal squares is laid down a base line or Abscissa, and along this are marked off the proper number of squares representing the different age-periods. On the base line is constructed a series of parallelograms of such a height that, in accordance with a scale of population given at the left-hand margin, the area of the parallelograms shall represent the total number of lives at risk for each age-period.

Thus, if for males the total number of lives at risk for ages 0-5 has been found to be 20,000, the parallelogram for this age-period should read to the height of $\frac{20,000}{5} = 4,000$, against the scale of population. A curved line is now drawn through the upper borders of these parallelograms, as free from bends and irregularities as possible, and in such a fashion that the area cut off from each parallelogram shall be equal to the area added to the same. The base line is already divided into equal spaces representing single years of life, and vertical lines are drawn through the centre of each of these spaces upwards to join the curved line. The height to the point of junction of each of these vertical lines with the curved line above referred to

is read off against the scale of population, and will give the lives or deaths for the middle of each year of age (*see* fig. 90).

The mean population (or the number of lives at risk) for each year of age during the ten years between two censuses may be calculated as follows: The population at the census of 1901, and again at the census of 1911, is first split up into its age and sex distribution in thirteen age-periods; the "central" population in the middle of 1901 and 1911 for each such group is then calculated logarithmetrically. The annual increase per unit for each age and sex group is next calculated (one-tenth of the log. of central population in 1911 – one-tenth of the log. of central population in 1901 = log. of annual increase per unit).

Now we have the mean total lives at risk in each age and sex group, and by means of the graphic method we may find the lives at risk for each year of life; and by similar methods we may deduce the mean number of deaths for each year.

If the lives at risk in any year constitute a "central" population for that year—and it is assumed that the deaths are uniformly distributed throughout that year—then the probability of surviving any one year =

$$\frac{\text{lives at risk} - \frac{1}{2}\text{ the deaths in the year}}{\text{lives at risk} + \frac{1}{2}\text{ the deaths in the year}};$$

and as the mortality rate for the year in question is, of course, a rate per 1,000, it follows that the number of persons living in any year multiplied by:

$$\frac{1{,}000 - \frac{1}{2}\text{ the mortality rate for that year}}{1{,}000 + \frac{1}{2}\text{ the mortality rate for that year}}$$

furnishes the number completing that year. Thus, if the mortality rate for the second year of life be taken as 24 per 1,000, and the survivors at the end of the first year of life be taken as 90,000, the probability of anyone surviving the second years of life =

$$\frac{1{,}000 - \frac{1}{2}\,24}{1{,}000 + \frac{1}{2}\,24} = \frac{988}{1{,}012};$$

and the survivors at the end of the second year of life would number $\frac{988}{1{,}012} \times 90{,}000 = 87{,}865$.

The most important columns of a life table for any population show the numbers surviving at each year of age, the years of

life lived subsequent to each year of age, the sum of the years lived in and after each year of age, and " the mean after-lifetime " or " expectation of life at any age."

The life table is very valuable for comparing the vitality of a community at one period with that of another period, or with that of another community. By furnishing, by the law of probability, the expectation of life of the different members of the community, it supplies a valuable comparative figure for vital statistical purposes, and one which, by enabling us to

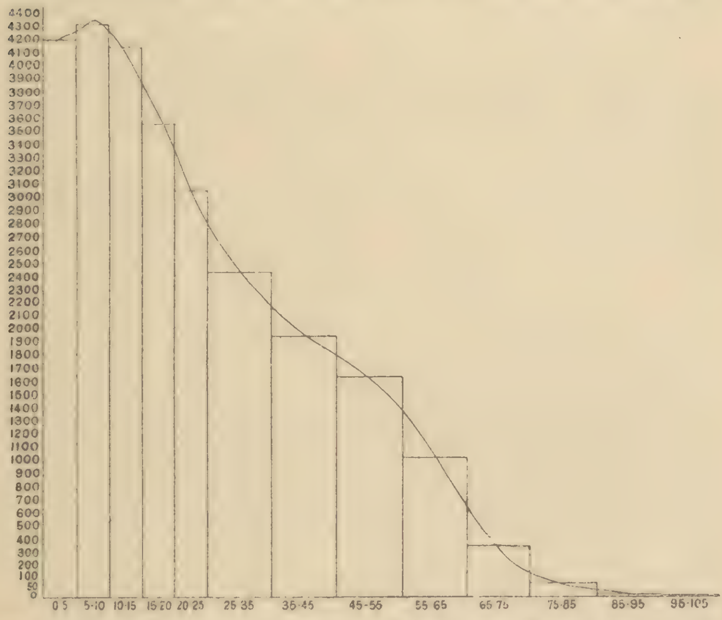


FIG. 90.—GRAPHIC METHOD. MALE POPULATION—NUMBERS LIVING OR LIVES AT RISK.

measure the probability of life and death, affords a scientific basis on which the calculations for life assurance are made. But accurately determined death rates at different age-periods give more detailed and equally accurate information, and the standardized death rate for all ages is as good an index of the vitality of a community as is the expectation of life at birth.

The *mean duration of life* or *expectation of life at birth* differs widely from the mean age at death, when the population is continuously disturbed by a fluctuating birth rate, immigration, and emigration, although when the population is stationary they

coincide. Thus, the mean duration of life in England (1881-90) for males, as calculated from a life table, was 43·66 years; whereas the mean age at death was only twenty-nine years. It must be borne in mind that this difference is due to the fact that the mean duration of life is calculated from life tables in which all the members of a hypothetical population are traced through life, while the mean age at death is a calculation based upon the actual registered deaths in a population disturbed by fluctuations of both immigration and emigration. Life tables show how many of a given number born live through each year of age, and what is the sum of the number of years they live; the sum of these years divided by the lives is the mean duration of life (mean after-lifetime at birth or expectation of life at birth). It is not the same thing as the *probable duration of life*, which is the age at which a given number of children born at the same time are reduced one-half; the chances, therefore, of their dying before or after that age being equal. The mean duration of life for males (English life table, 1891-1900) was 44·13 years, whilst the probable duration of life was about 53 years.

Mean after-lifetime is a more accurate expression than expectation of life, as, strictly speaking, the time which it is expected a person will live is the time which it is an even chance he will live. But it has been thought advisable to retain here the term "expectation of life," as being the term usually employed in life tables.[1] It must be understood, however, to mean, whenever expressed, the mean after-lifetime, and not the probable duration of life.

The following table shows the expectation of life, in decades, from 1871-80:

1871–1880	41·0 years.
1881–1890	43·7 ,,
1891–1900	44·1 ,,
1901–1910	43·9 ,,
1911–1920	51·5 ,,

The increased expectation of life to-day is due to years saved during the younger and more useful period of life, for a man of 70 has the same expectation of life—namely, 13 years—now as in 1871.

It has been shown by the late Professor de Chaumont that the

[1] The English Life Table for 1891-1900 and many earlier life tables will be found in the Supplement to the 65th Annual Report of the Registrar-General (Part I.).

mean duration of life may be approximately calculated from the birth rate and death rate by the following formula: where b = birth rate per unit of the population, and d = death rate per unit of the population.

Then *mean duration of life* $= \left\{\frac{2}{3} \times \frac{1}{d}\right\} + \left\{\frac{1}{3} \times \frac{1}{b}\right\}$.

This formula, however, is really only applicable when the birth rates do not depart much from the average of the whole country.

Dr. Tatham has shown how a figure, representing what he terms "life capital," can be obtained with the assistance of a life table. If the most recent mortality returns for a single year are compared with the mean of those obtained for a succession of the years immediately preceding, the comparison will generally be a favourable one to the most recent year. The difference in the number of deaths will be the lives saved to the community. If each life gained be multiplied by the mean expectation of life for the corresponding age-period, we obtain the gain of life capital for the community for each age-period, and from this the gain for the whole community can be ascertained.

Life tables not only furnish the mean duration of life or the expectation of life at birth, but also the *mean after-lifetime* or *the expectation of life at any age*—that is, the length of time a person of any age may be expected to live. The expectation of life at any age is calculated from the numbers living at the age in question and from the years of life they subsequently live, just as is the mean duration of life (expectation of life at birth). For ages between twenty-five and seventy-five, Willich's formula also gives approximate results.

If x = expectation of life, and a = present age, then $x = \frac{2}{3}(80 - a)$.

The death rates of infants under one year, and of children under five years, are most important, as they afford very positive evidence of the sanitary circumstances of a community. The death rates of infants under one year should be stated as so many deaths in a year to 1,000 registered births, this rate being known as the "*rate of infantile mortality*." This rate has the advantage that it can be computed with certainty from an accurate register of births and deaths; whereas the other death rates, except in census years, have to be calculated from an *estimated* population, and are not, therefore, so accurate.

The *rate of infantile mortality* is liable to considerable fluctuations year by year, the fluctuations being largely determined

by the increased or diminished incidence of summer diarrhœa. The rate in this country furnished no evidence of any continuous reduction until quite recently, and the deaths under one year of age still continued to form some 16 per cent. of the total deaths in 1920. The chief registered causes of infantile mortality are as follows:—Debility, wasting, congenital defects, prematurity of birth, diarrhœa, measles and whooping-cough, convulsions, accidents (including "overlying"), bronchitis and pneumonia. Seventy per cent. of the total infantile mortality is generally ascribed to the above-mentioned causes. The rate of infantile mortality among illegitimate children is about double that of children born in wedlock.

The following table shows the proportion of the total deaths of infants under one year of age to 1,000 births contributed by

INFANT MORTALITY BY SEX AND LEGITIMACY (ENGLAND AND WALES), 1920.

	Deaths per 1,000 Births.	
	Male.	Female.
All causes :		
Under 4 weeks	39·69	30·43
4 weeks–3 months	18·25	13·00
3–6 months	14·02	10·86
6–9 months	10·18	8·38
9–12 months	7·88	6·64
Total under one year	90·02	69·31
All ages under one year :		
Whooping-cough	2·05	2·45
Other common infectious diseases ..	2·08	1·82
Influenza	0·64	0·46
Diarrhœa and enteritis	9·25	6·64
Premature birth	19·79	16·25
Congenital defects..	6·16	5·04
Atrophy, debility, and marasmus ..	10·30	7·23
Developmental and wasting diseases ..	36·25	28·52
Tuberculous diseases	1·66	1·26
Convulsions	6·37	4·75
Bronchitis and pneumonia	19·81	14·80
Other causes	11·91	8·61
All causes	90·02	69·31

various causes in England and Wales in 1920. The deaths from premature birth and congenital defects (atelectasis, patent foramen ovale, cleft palate, imperforate anus, spina bifida, etc.) form

nearly 29 per cent. of the total, and occur chiefly within four weeks of birth. The percentage due to diarrhœal diseases in any year will be largely dependent on the temperature of July, August, and September; whilst the percentage due to bronchitis and pneumonia will be governed by the severity of the winter and spring, and the presence or absence of whooping-cough and measles in epidemic form.

Infantile mortality is usually highest in the districts having a very high birth rate; this is probably due to the fact that high birth rates occur in relatively poor-class communities. It is higher in urban than in rural districts, among illegitimate than legitimate children, and among the industrial than other classes of the population.

The decline in the infantile mortality rate in England and Wales commenced about the year 1900, and with the exception of the year 1904, has continued to the present time.

INFANTILE MORTALITY.

Year.	Rate.	Year.	Rate.
1871–1880	149	1901–1910	128
1881–1890	142	1911–1920	100
1891–1900	153		

Over one-third of the deaths of children under one year of age occur during the first month of life, and about one-fifth during the first week; nearly two-thirds occur during the first three months. This circumstance is largely accounted for by unfavourable ante-natal conditions.

The deaths of children under five should be stated as death rates per 1,000 living under that age. The average rate for male children for England and Wales, 1913, was 39·2 per 1,000, for female children 32·2 per 1,000, and of both sexes 35·7. No doubt some part of this infant and child mortality, which is preventable, is due to other causes than insanitary conditions controllable by local authorities, such other causes being maternal neglect, insufficient and improper nourishment, etc. Still, just as a sustained rate of general mortality above 17 per 1,000 always implies unfavourable sanitary conditions (Dr. Farr), so it may be said that rates of mortality amongst infants and young children, which exceed the rates prevalent in the country generally, are mainly indications of bad sanitary conditions in the communities in which they occur, and of ignorance or neglect on the part of the mothers.

The importance of a right use of vital statistics, and of avoiding unfounded and erroneous deductions, is so great that it will be well to further indicate some of the errors and fallacies, which are either inseparable from, or are introduced into, the subject.

In the first place, the data derived from the census returns are incomplete and sometimes fallacious: *e.g.*, old people are often ignorant of their precise age, and frequently overstate it when very old; females often wilfully misstate their ages; and young children are often returned as one or two years old when they are only in their first and second years. Again, the population is only an estimate in the intercensal periods, and considerable errors in the estimation often arise; it is for this reason that a five-yearly census is so much to be desired. The registration of births and deaths, and the certification of the causes of deaths, are subject to many fallacies, arising from faulty diagnosis, indefinite certification, and the lack of uniformity in the nomenclature of disease; whilst many births escape certification from ignorance, shame of illegitimacy, or from the parents' desire to avoid vaccination. The use of such terms as "convulsions," "jaundice," and "dropsy," for instance, should be avoided, whenever the true cause of these symptoms can with reasonable certainty be substituted. It is impossible, also, to correctly classify deaths which are returned as due to two or three distinct maladies, without any indication as to which was the primary cause of death. Various classifications of deaths have been suggested and employed; they may be based on symptoms, causes, the tissues and organs affected, or the parts of the body affected considered anatomically. The latter is the classification suggested by Farr and Bertillon; and it probably ensures a greater precision in classification, and favours a more just comparison of the deaths from various causes than any other.

The Society of Medical Officers of Health has issued certain rules as to the classification of causes of death. It is advised as a general rule to select, when several diseases are mentioned in a certificate, the disease of the longest duration, but any one of the chief infective diseases should be selected in preference to any other cause of death; and definite diseases, ordinarily known as "constitutional diseases," should have preference over those known as local diseases. When apoplexy occurs in conjunction with definite disease of the heart or kidneys, the heart or kidney disease, as the case may be, should be preferred; and when

hemiplegia is certified in conjunction with embolism, the embolism should be selected. If a death is registered as being caused by two diseases, if one of the two diseases is an *immediate and frequent* complication of the other, the death should be classified under the head of the primary disease. Examples:—

Infantile diarrhœa and *convulsions*, classify as *infantile diarrhœa.*

Measles and *broncho-pneumonia*, classify as *measles.*

Scarlet fever and *nephritis*, classify as *scarlet fever.*

Diarrhœa should be ascribed as the cause of death only when mentioned alone or in connection with some other definite cause, such as convulsions, teething, marasmus, etc. In addition to deaths ascribed to diarrhœa alone or as above indicated in the certificate, deaths from *intestinal catarrh*, *epidemic enteritis*, or *zymotic enteritis*, should be included under *diarrhœa.* But deaths from *gastric catarrh*, as well as from *gastro-enteritis* and *enteritis* (without the prefix *epidemic* or *zymotic*), should be excluded. The Registrar-General classifies such deaths under (1) epidemic diarrhœa and infective enteritis (including deaths from diarrhœa due to food), and (2) diarrhœa not otherwise defined; and the diarrhœa death rate is calculated from the deaths from diarrhœa and enteritis under two years of age.

The death rate of seaside places is seldom correct. A certain number of visitors are always included in the estimation of the population, and it is not easy to exclude their deaths. The domestic servants in a community introduce a further fallacy in vital statistics, since they rarely die in service. Although counted in the population of the district where they reside, they frequently return to their homes in other districts, when seriously ill and unfit for further service.

The death rates of general hospitals can never be justly compared, because of the varying nature and gravity of the cases admitted from time to time, the varying proportion of medical to surgical beds, etc. The death rate is often stated as the number of deaths to every 100 occupied beds, but it is better to express the deaths as a ratio of the number of cases treated to a termination.

Occupation plays an important part in determining mortality, some occupations being far more healthy than others. *Occupational mortality* is calculated from the deaths occurring in any particular occupation. For purposes of comparison the death rates among those employed at corresponding age-periods must

be taken, allowance being thus made for the varying age constitution of those engaged in the different occupations. A *comparative mortality figure* for different occupations may be obtained by taking the deaths occurring in a *standard population*, such standard population to consist of the exact number of males in the whole population between twenty-five and sixty-five years of age, who would supply 1,000 deaths annually. Dealing with the deaths of 1890-92 and the population of 1891, Dr. Tatham showed that 1,000 deaths occurred among 61,215 males between twenty-five and sixty-five years of age; whereas the number of deaths among a similar number of medical practitioners only amounted to 966; or, in other words, the same number of men aged twenty-five to sixty-five (having equal numbers at the various inclusive ages) that would furnish 1,000 deaths among all males, would only give 966 among medical practitioners.

Example :

Ages.	Standard Population.	Death Rate per 1,000 living in each Group among—		Calculated Number of Deaths in Standard Population among—	
		All Males.	Medical. Practitioners.	All Males.	Medical Practitioners.
25–35 ..	22,586	7·67	6·69	173	151
35–45 ..	17,418	13·01	14·92	227	260
45–55 ..	12,885	21·37	21·04	275	271
55–65 ..	8,326	39·01	34·16	325	284
	61,215			1,000	966

An obvious fallacy in any attempt to gauge the relative healthiness of different occupations results from the fact that certain occupations attract the more robust and muscular, whilst others demanding less strength attract the weaklings.

The mean age at death cannot be taken as an index of the healthiness of an occupation, because some employments are filled by older men, who have proved their worth or have filled minor posts during many years, while other classes of labour requiring less skill and experience are much more largely filled by those young in life.

Instances of the more usually employed graphic methods of representing statistical results can be seen in the annual reports of medical officers of health. Erroneous conclusions are apt to

be formed by comparing the mortality curves on scales which are not identical. "Spot maps"—maps of the district, on which the deaths or cases of various infectious diseases are indicated on the locality where they occur—furnish valuable graphic expressions of any grouping of such deaths or sickness, and are much employed by medical officers of health. They should, however, usually be employed to express these occurrences for short periods only. Spot maps, covering a period of several months or a year, are not often of much value for the purpose which they are designed to subserve.

INDEX

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